Master's Thesis

AngGo-N: Transformable Personal Mobility Providing The Autonomous and Manual Driving Mode

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Executive Summary

This thesis describes the development of a Shared Indoor Smart Mobility device called AngGo-N. During the development process, We conducted researches and studies on PMVs(Personal Mobility Vehicles) and AngGo. AngGo is the indoor personal mobility finding potential users who need indoor transportation movements. The goal was to develop Shared Indoor Smart Mobility and to ensure AngGo-N meet user requirements practically. This study contributes to how a Shared Indoor Smart Mobility can meet transport users' needs around an indoor environment. We state two research questions to develop AngGo-N. The first one is 'How to improve the acceptance of the SISM?'. The second one is 'What is the needed design implication of SISM?'. Based on AngGo's problems, We found solutions to them and apply them to AngGo-N's design. We applied transformable factors in AngGo-N to give interaction between user and personal mobility. The AngGo-N give user different forms in autonomous mode and user-controlled manual mode. After making the prototype of AngGo-N, We do competitive testing and value opportunity analysis. With the result of the analysis, We make answers for those two research questions.

Keywords: Transformable Personal Mobility Vehicle, The Indoor Mobility, Shared Indoor Smart Mobility, SISM, AngGo, AngGo-N

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Explanation of Terms and Abbreviations

Terms and Abbreviations	Explanation
Personal Mobility	Personal mobility is divided mainly into PMD(Personal Mobility Device) and PMV(Personal Mobility Vehicle). It has the characteristic of using electricity as the primary power source.
Personal Mobility Vehicle (PMV)	Vehicles subject to the domestic automobile management law among personal mobile devices. Personal Mobility Vehicle is composed of a shape equipped with lighting devices, braking devices, steering devices, and riding devices while maintaining a car or two-wheeled vehicle's chassis and body.
Personal Mobility Device (PMD)	Among personal mobility devices, products subject to the Electrical Appliances and Household Goods Safety Management Act. Personal mobility Device has a relatively simple structure and lightweight. There are Segway and Electric Kickboard that sold worldwide.
AngGo	The Shared Indoor smart mobility platform that developed in the UNIST DECS lab. In 2020-12-15, the third version of the product was coming out[36].
AngGo-N	The transformable type of Shared Indoor Smart Mobility platform introduced and developed in this paper.
Smart Mobility	The mobility forms of transport that can transfer users to their destination.
Micro-mobility	Mobility constitutes forms of transp006Frt that can occupy space alongside bicycles. Multiple criteria can be applied to define micro-mobility[8]. Weight is less than 500kg, passenger or payload capacity, powertrain(human-powered or electric), maximum speeds or ranges, and others[41].
SISM	Shared Indoor Smart Mobility.
SIOSM	Shared Indoor & Outdoor Smart Mobility.
Value Opportunity Analysis (VOA)	Value opportunity analysis maps the extent to which a product's aspirational qualities align with people's idealized lifestyle or a fantasy version of themselves[25]. A technique can be used to identify the aspirational attributes of a product or service.[26]
Competitive Testing	Competitive testing is the process of researching to evaluate the useability and learnability of our competitors' products[25]. Competitive testing provides design teams with an opportunity to assess competitors' products from the end user's perspective [39]. According to studies, the difference between our site and our competitors' can reveal a 68% gap in useability[42].

1

Introduction

- Background
- Related Works
- Developing a New Type of Micro-mobility
- Research Aim and Method
- Thesis Structure

1. Introduction

Background

Recent innovations, such as electric scooters, shared bikes with and without docks, and personal mobility devices, reduce personal vehicles' need to transport people at short distances. Micro-mobility means short distance transport using a personal mobility device such as kickboards, Segway, and mini electric scooters. Users have welcomed the rapid introduction of these devices in recent years. Micro-mobility services have also drawn positive responses from users. The introduction of appropriate size devices for a particular space enables better utilization of these spaces, reducing greenhouse gas emissions [1]. More than half of the world's population currently resides in urban areas. This ratio is expected to increase by two-thirds by 2050 [2]. Therefore, in all modes of transport, the demand for mobility of urban passengers will double from 2015 to 2050, all of whom will need proper transportation methods [3]. Similar requirements exist for indoor environments, despite several types of micro-mobility devices for outdoor use. Walking in vast spaces such as military bases, airports, shopping malls, conference centers, or fairgrounds can be exhausting for some people. It can detract from their enjoyment of the exhibits or the full achievement of their visits' particular purpose.

Previously, Smart Mobility refers to products that use a motor, gyro-sensor, and acceleration sensors. However, now it is hard to find the difference between Smart Mobility and personal mobility because of technologies. Thus, smart mobility includes electric bicycles and electric scooters from a general point of view. As products that are not smart begin to be included, the term Personal Mobility Vehicle is also being used. This means that a new mobility type has come out. At the same time, the form and functions should be developed for new Personal Mobility Vehicles.

This thesis proposes a shared indoor smart mobility (SISM) device, an autonomous platform with a seat that allows users to sit when they move in an internal environment. The indoor mobility devices' design shall consider the operation modes, appearance, and interaction systems comforting a given indoor environment. We applied sensors to set up a system that allows the

SISM device to navigate an indoor environment without colliding with obstacles indoors while recognizing potential users as they approach.

Related Works

Future states of mobility

Several technological and social progress is radically changing the way people are transported, affecting many industries. With this trend, four types of mobility have emerged within the new mobility ecosystem have emerged. This occurs at the intersection of the person who owns and drives the vehicle (Figure 1)[36].

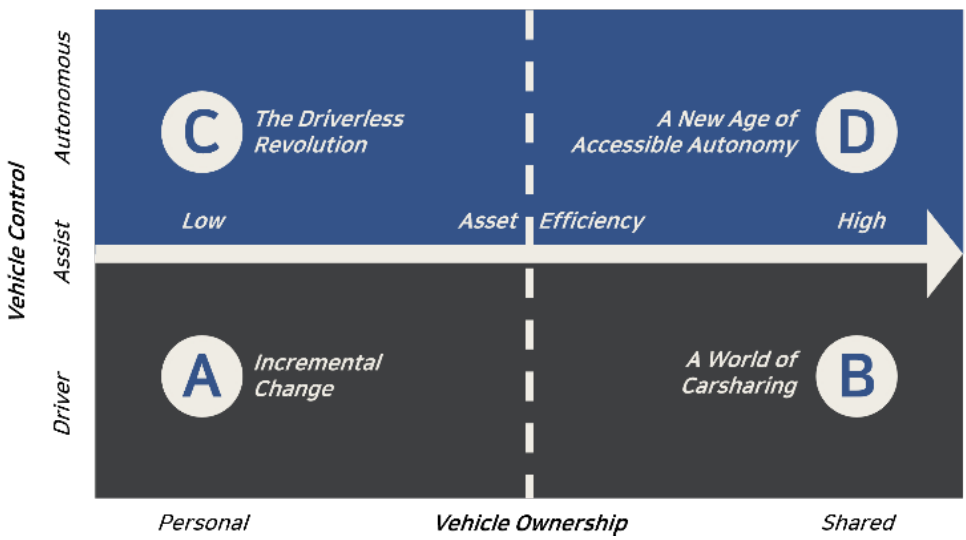


Figure 1. Future states of mobility[4]

Privately owned mobility

This, called private property mobility, will still be a gold standard as consumers choose flexibility, privacy, convenience, and safety. As they like to drive alone, even though it is its advanced technology, it is assumed that the driver's auxiliary power source will not be replaced.

Shared mobility

It is expected that co-mobility will continue to increase through the use of shared vehicles or car sharing. Motivated by expanded markets and competition, car-sharing services will be increasingly promoted as part of the novel and specialized customer segments. Shared mobility will account for a significant portion of regional transport needs. The number of households with more than one vehicle will be reduced. Likewise, many people are likely to stop owning mobility.

Privately owned driverless mobility

Drivers will choose more and more for safety and comfort reasons. However, autonomous driving technology for safe and economical means for general mobility is still at level 2 [21]. People still expect highly customized vehicle expansion within the country market to meet homes or individuals' specific needs.

Shared driverless mobility

Autonomous driving and car-sharing are expected to converge in the form of driverless shared mobility. Mobility management firms and fleet operators provide extensive customer experience to meet this need from different perspectives. In the future, it will provide mobility in the form of a faster, safer, cleaner, and more convenient overall system.

Developing a New Type of Micro-mobility

Micro-mobility is essential so that in areas where a high proportion of the population depends on public transport and at the same time, adaptive transport is readily available. The population that relies on public transport includes people with physical disabilities or lacking a driver's license [5]. These groups require micro-mobility to access public transport. Micro-mobility solutions can also provide short trips within confined spaces, such as universities, corporate campuses, and military bases. It is worth noting that public transport consists mainly of short-distance mobility. For example, the average distances people travel by bus, train, and tram are 3km, 6km, and 8km, respectively. Thus, some of these modes of transport can potentially be replaced by micro-mobility solutions. Oliver Bruce, an investor that also propagates micro-mobility, estimates that more than 2.2 trillion km of U.S. passengers' annual travel and more than 6.4 trillion km of worldwide annual travel could be replaced micro-mobility devices[8]. Thus, micro-mobility is targeting a market worth potentially hundreds of billions of dollars and deserves serious consideration [6]. Any city can introduce micro-mobility into a new test case in the management system. This initiative can be sponsored by a digital platform integrated into a single group to accommodate all available vehicles to supply and demand optimization and create the highest global efficiency across systems [7]. However, some industry leaders have pointed out that others are ostensibly discussing possible vehicle performance, shape, and size. These leaders have also predicted the emergence of new and multi-faceted designs that will expand the definition of what we consider micro-mobility [8].

Before developing a new type of personal mobility, we search for previous work for indoor mobility development. An in-depth analysis was conducted in another thesis to understand why the most popular Xiaomi Segway, scooter, and kickboard models cannot be used for indoor mobility[9]. In an experiment that consisted of 24 healthy men and women between the ages of 20 and 30, he asked subjects to ride on their respective test mobility devices in the building for 10 minutes. The indoor test rides were conducted with three currently available outdoor mobility devices (Figure 2)[9].

Research Aim and Scope

This is the main research question about developing the Shared Indoor Smart Mobility platform based on useability, interaction, and design development process. To answer two research questions, we conducted competitive Testing with AngGo and a new type of mobility.

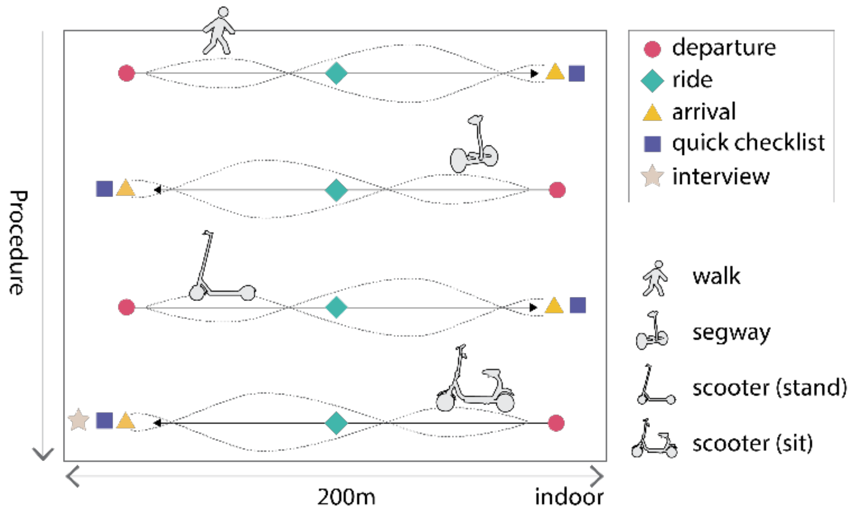


Figure 2. Experiment procedure [9]

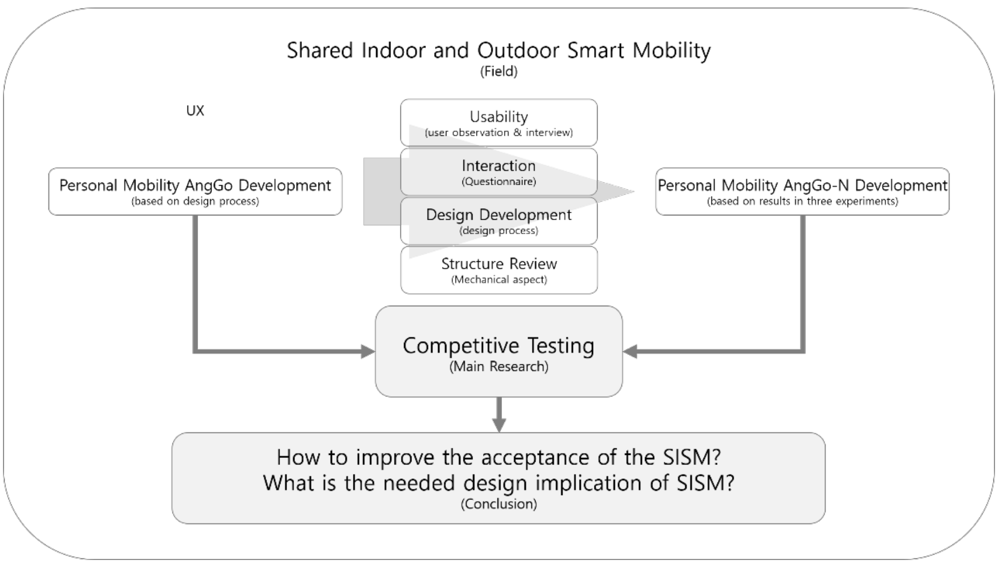


Figure 3. Research Aim and Scope

Thesis Structure

In Chapter One, we set the aims and scope of this research based on our research motivation. We investigate the research methodology's practical basis—Research through Design and prove—and describe our approach as research through prototyping from the lab. In Chapter Two, we emphasize the whole process of how we make the AngGo platform within the SISM concept. Physical appearance is explained based on design research and the expected appearance of the AngGo. Overall systems of the AngGo are expressed based on sensor selection, system details, system implementation for semi-autonomous mode, and system implementation for manual mode. Chapter Three proceeded with the useability test, interaction test, developers' interview, and structure review with SISM AngGo. Usability test in manual mode. The interaction test was about interaction experiments in autonomous mode. AngGo developer interview was about design implementation in the indoor and outdoor environment.

The structure review was also done to see a detailed design. Based on this research, we listed all findings. Moreover, we arranged and put together results in interim results in Chapter Four. In Chapter Four, we introduced developed SISM mobility AngGo-N based on insights in previous researches. Overall systems of the AngGo-N are introduced. The prototype development procedure is listed, with the implementation process. We run competitive testing with AngGo and AngGo-N within the same environment. Research questions, participants, experiment description, results were listed in chapter Five. Next, we discussed experiment results, which are run in Chapter Six. Limitations of this thesis are listed in it. Finally, we concluded our master thesis about Shared Indoor Smart Mobility development. Moreover, further works topic came out in here Chapter Seven.

2
Preliminary Study
SISM development

- Physical Appearance of the AngGo
- Expected product performance of the AngGo
- Conclusion of Preliminary Study

2. Preliminary Study

Subsequently, we administered interviews and questionnaires based on their experiences with the mobility devices they tested [9]. Following the indoor test drives' survey results, we created a diagram, shown in Fig. 3, that depicts user experiences. The seated e-Scooter received the highest overall score. In contrast, the Segway, which is operated by leaning the users' body, scored low on the "universally accessible" test parameter because it was difficult to manipulate. Subjects were asked to name the essential factor to consider when designing a shared indoor mobility device. The 24 responses were classified into four value categories: 13 subjects declared convenience, 9 chose safety, chose to trust, and chose aesthetics. Based on these results and further analysis of the interview results and keyword extraction results, we determined that relief, notice, and amusement were the three essential components for our SISM system. The SISM device was designed to consider the subjects' opinions, which were classified according to four parameters: accurate and safe control, rider comfort, trunk storage, and amuse hands-free operation. To allow a more intuitive operation mode for SISM users, the system was designed to be controlled with both feet. We developed a foot-controlled SISM mode of operation, which is represented by corresponding sketches and models. The conceptual design defined the structure for pushing and pulling the pedal plate. The pedal plate was designed to accommodate the user's feet up to 300 mm in size. The surveyed users' posture determined the device's actual size and riding posture. For the useability test of the pedal plate, we built a platform called AngGo, as a prototype of the SISM device proposed in this thesis (Figure 4) [36], [37], [38].

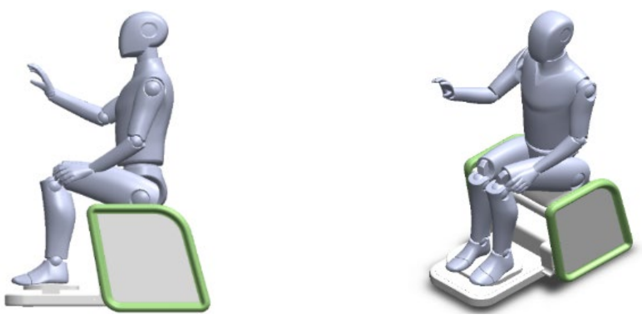


Figure 4. Model of AngGo platform[36]

The AngGo

The primary function of a seat for users to sit. The seat's endpoint was taken to match its appearance with the structure containing the rear side's curvature. To keep the user's hand free during operation, a pedal plate was added. The saddle and trunk were designed by applying flat elements (e.g., the pedal plate) to the platform's body. An intuitive parallelogram-shaped lateral body impression was added by introducing curvature. By giving the design a larger curvature at the rear part of the side body, the design has a forward lean direction. The SISM main body aligns with the side body lean. The side body's top line was designed to be higher than the saddle so that the users could safely sit and hold on if necessary. The pedal plate was designed to have a slight incline to make it easier to push and pull it when in use. The curvature of the pedal plate was also designed to provide clues to directionality. This was achieved by designing the front with a larger curvature, thus giving clues about the direction of movement (Figure 4).

Table 1. AngGo Specifications[38]

Dimensions (L x W x H)	**120 cm x 80 cm x 60 cm**
Weight	20 kg
Maximum load	100 kg
Maximum speed	8.0 km/h
Operation time per charge	5 hours
Power supply	36 V, 10 Ah

Expected product performance of the AngGo

The AngGo Platform has a maximum 120mm x 800mm x 600mm width to provide enough space to sit comfortably. The maximum load was set at 100 kg as it is designed to accommodate a single user. The maximum speed was set to 8 km/h, similar to the average person's fast walking speed. Its primary function is indoor mobility. The AngGo also has the function of avoiding collisions with people walking in the same space. The AngGo was designed with a total weight of less than 20 kg. The battery capacity was set accordingly, aiming for a runtime of 300 minutes per charge (Table 1).

Conclusion of the preliminary study

AngGo interacts with users by making light and sound interaction on the seat side. However, these kinds of interactions make limitations in the noisy or lighting indoor environment. To overcome these limitations, we apply transformable interaction to personal mobility. The definition of transformable design has three conditions. The transformable design can transform from one state with unique functionality and physical form to another state with another functionality and physical form. These individual states can exist in two or more states. The product variations should be intended in the design process. Deformation must be reversible, and the product is not separated after transformation. More advanced technology and a high difficulty design process are required to design and apply the transformable structure in personal mobility. However, through this, it is thought that it will be possible to save space and time resources that the product continuously occupies and improve useability and functionality. With the development of technology, foldable display smartphones that were not previously commercialized appear on the market. The improvement in useability due to the change in functionality made through the transformable is well received. [35]

3

Problems of the AngGo

Tests and Evaluation of AngGo

- Usability Test
- Interaction Test
- Focus Group Interview: AngGo Developers
- Mechanical Review
- Summary and Findings

3. Problems of the AngGo

Field experiments were conducted to test the AngGo prototype and determine how efficiently this SISM platform can be implemented. The experiment was carried out in the first-floor lobby of a UNIST building, measuring 3000cm x 12000cm (Figure 6). Pedestrians getting through the building were not prevented during the test. The field experiment took about an hour, and fourteen people went through the entire process of interacting with the AngGo. Evaluate the design elements of overall useability and mobility while measuring footplate manipulation's intuition and learning ability. Simultaneously, we tried to extract design elements deeply related to our ability to learn intuition operate the foot pedal. The critical criteria for evaluating this observation experiment were the three values pursued in the AngGo platform development process: relieve, notice, and amuse.

Figure 5. Setup of the obstacle evasion

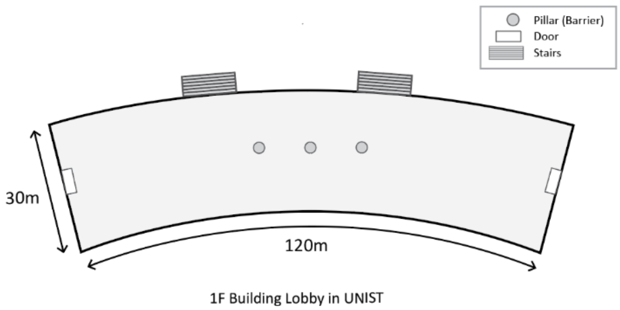


Figure 6. Test layout[9]

Usability Test

The algorithm switching between manual and autonomous modes, which was the proposed SISM system's goal, worked successfully as designed. In Figure 7, the Usefulness of manipulating mobility by footplate has resulted in 4.64 average scores of 4.46 and 4.42 in questions 1 and 2. Both hands were partially free, with a score of 4.00. Getting off mobility was partially safe, with a score of 3.93. Pedal length and degree of rotating will be revised appropriately based on questions 5 and 6. Nine riders responded positively to the value "relieve" and reported a comfortable riding experience with a score of 5. The value "amuses" also obtained a positive answer, relative to foot-controlled manual driving mode (Figure 8).

This is the list of questions in Figure 7.

① Was it easy to learn how to manipulate mobility with your feet?

② Was the foot-manipulating method intuitive?

③ Were both hands free to drive?

④ Was it safe to get off?

⑤ Was the level of footrest moving back and forth appropriate?

⑥ Was the level of rotating foot pedal appropriate?

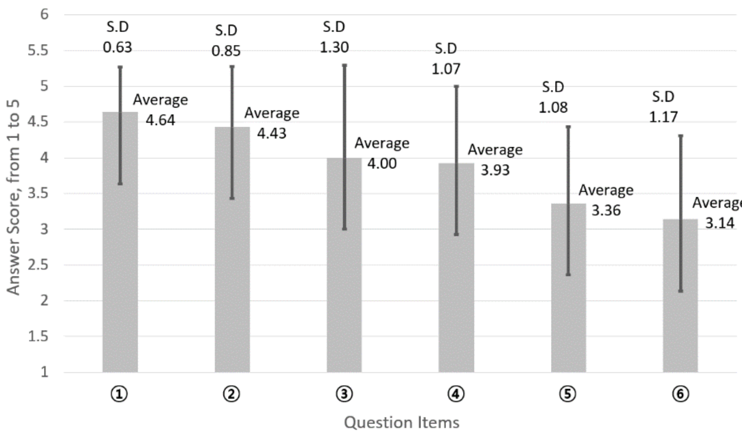


Figure 7. AngGo mobility useability test survey results[38]

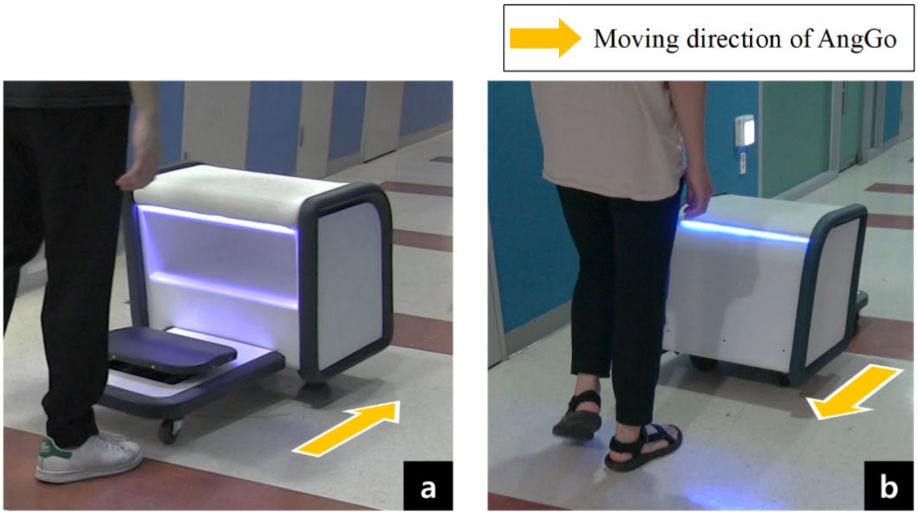
Usability Test Discussion

Drivers of the AngGo and passersby inside the building were unsure if the AngGo was in autonomous or manual mode. This will need to be improved by providing visual feedback on the SISM platform's operational status via LED displays or notifications. Manipulating the pedal plate in manual mode was reasonably comfortable for riders to use, even if they had no prior experience with AngGo. They could freely wander around the lobby, comfortably seated in AngGo's seat. They could greet passersby or carry objects with both hands-frees, as initial design concepts intended. The AngGo also responded well to users jumping without approaching from the front or following behind. In such cases, AngGo instantly entered manual mode and skipped standby mode. An observational experiment was carried out in the lobby of a building to test both autonomous modes—the AngGo Platform navigated in search of a potential rider, and the manual mode. The users drove it with a pedal plate. Based on this experiment's results, we established a set of optimized parameters and adjusted performance accordingly. In this experiment, we also found that more than half of the participants answered that they need a backseat and armrest while driving.

Figure 8. Rider posture when in use[38]

Interaction Test

The second experiment was conducted with other researchers. The influence of personal mobility vehicles (PMVs) has been expanding into the indoor context, and the shift from personal vehicle ownership to shared mobility is underway. Thus, a new method for user-vehicle interaction is needed. The following and blocking methods were proposed previously for changing the driving mode of AngGo, a shared indoor smart mobility (SISM) vehicle; however, these methods were not evaluated. We evaluated both these methods' workload, added visual and auditory feedback, and validated their effects through a user-based study. Our study reveals insignificant differences between the workloads of the two mode-change methods. Auditory feedback shortens the reaction time as the user cannot recognize whether AngGo detects the user or not. Visual feedback is significantly preferred to auditory feedback, while bimodal feedback is more intuitive than auditory feedback. Our findings contribute to the interaction design considering shared PMVs in an indoor context.



(a) Visual feedback for the following method, (b) Visual feedback for the blocking method

Figure 9. Visual feedback using LED strips inserted right below the seat

Test environment

Our experiments are similar to the context of the natural interaction experiments. AngGo is placed 4.5 m from each participant before the start of each experiment. The sunlight is entirely blocked, and all ceiling lights are turned on in the hallway. The noise level is controlled within 40–50 dB, and the auditory stimulus reaches approximately 70 dB. The experiment environment's width and height are 2m and 10 m, respectively (Figure 10, Figure 11). We recorded a video of each subject to obtain a reaction time, which is when the time feedback appeared when the subject started to move. To record the participants' activity, the camcorder was placed at the center of the hallway.

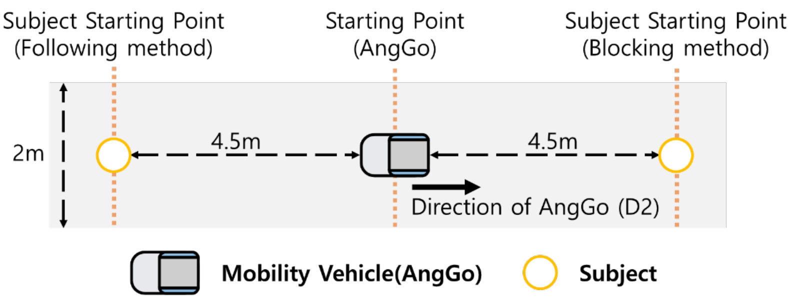


Figure 10. Map of the test environment and the initial location of AngGo and subject

(a) Visual feedback for the following method, (b) Visual feedback for the blocking method

Figure 11. Test environment

Modality Reaction Time

The participants' reaction time was measured by analyzing a video frame from the time the feedback was revealed to the moment the subject tried to move the participant's foot. The frame per second of the camcorder used was 29.97. Four participants were excluded because of the missing values due to video problems. The feet were not adequately captured. The box plot of the reaction time is shown in Figure 12.

The reaction time by feedback was statistically compared among 16 participants using the repeated method ANOVA for both mode-change methods. Results of Mauchly's test showed a violation of the sphericity assumption for the input reaction time in the following method ($p = 0.007$). Therefore, we used Greenhouse-Geiser correction to adjust the degree of freedom in the following method ($\varepsilon = 0.665$). We used the Tukey correction for all posthoc tests to prevent inflation of the type-I error.

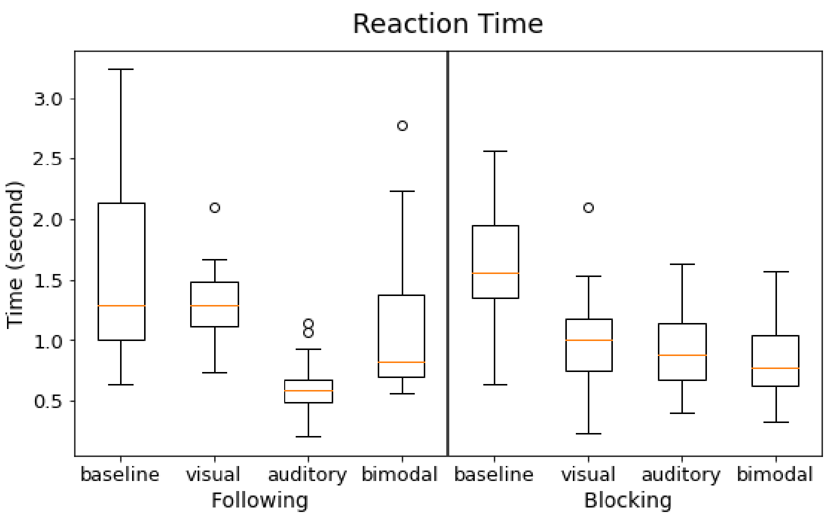


Figure 12. Box plot for reaction time, bimodal (visual&auditory), o = outliers

Focus Group Interview: AngGo Developers

Before entering revision, the AngGo, we gathered four people who experience mobility development from 6 months to 24 months. The form of the workshop has an open question structured workshop, and it took around 90 minutes. One designer and three engineers participated in this experiment.

Research Question

The interview had an open question workshop, so we settled on two big research questions. Each member was asked to write their own opinion on paper. After they wrote opinions about the research question, they proposed their ideas to everyone. By generalizing all answers, we converge all ideas and research questions in these two. 'How to improve the acceptance of the SISM?' and 'What is the needed design implication of SISM?'

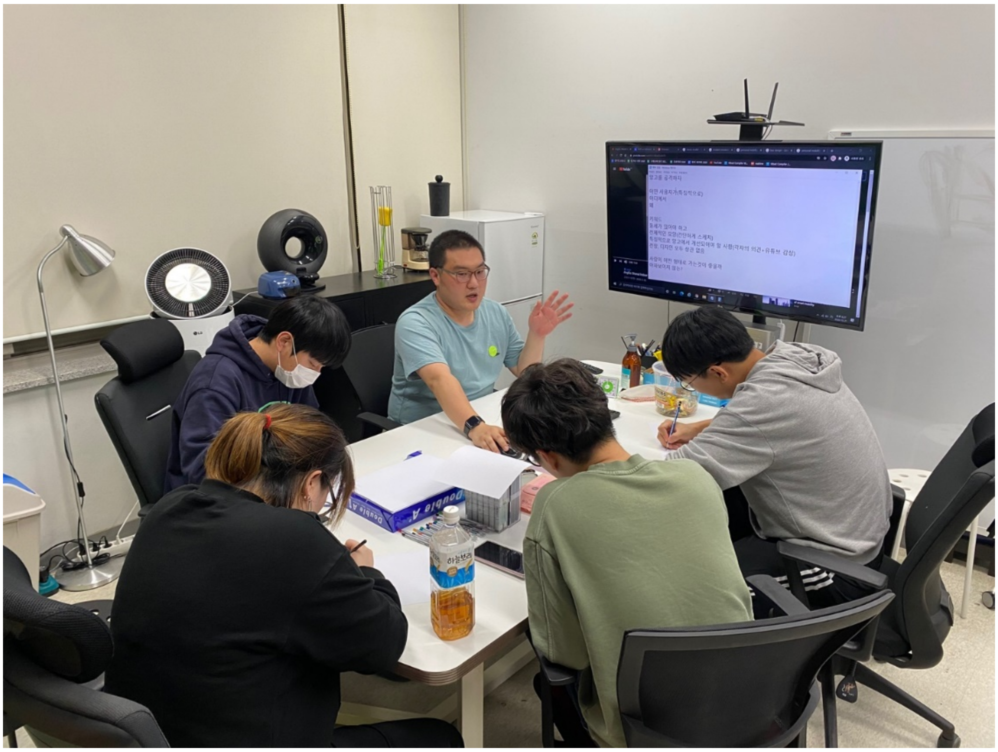


Figure 13. Interview with AngGo Developers

Aesthetic Design Mood board

We selected about 100 images via Red dot Awards and Behance. During this workshop, we asked participants to select the most proper moods for the SISM product. Results of the mood board are in Chapter Five, Design Features section.

Select Key Words

During the interview, we recorded all discussions and wrapped up writings. After we listened and saw through all the interview results and made a keywords list, all keywords are frequently used by participants. Results of extracted keywords are in Chapter Five, Design Development Procedure section.

Interview Discussion

All developers discussed two research questions. From every discussed topic, we extract seven vital critical points to be improved.

1. It needs a different posture in use. Users slightly bent when in use, so it needs to be hidden or make a different posture.

2. It needs robustness. Every mobility needs strong credibility to use.

3. It needs stability for users and pedestrians. Since it moves at a certain speed indoors, people should know its safety in design.

4. It needs to be sat posture for users. When users ride at more than a certain height, they are more at risk of being dropped.

5. The users do not ride or get off in the side of mobility. When the user rides on the left or right side of mobility, it gives feelings of falling.

6. The size of mobility should be compact for indoors and drive experience.

7. Information about the speed of mobility should be given to users.

Mechanical Review

The AngGo has two different versions of the prototype. Two prototypes have similar structure and weight, but it shows differently when in autonomous mode. The prototype shows a smooth turn for evading obstacles, but the second prototype shows difficulties in use. This analysis's purpose was to discover the factors that affect the drive. The first different factor of the two prototypes was the position of the casters. The prototype has a shorter interval between casters than the second prototype. The second difference between the two prototypes was the wheelbase difference. The wheelbase is the distance between front-wheel center points and back wheel center points. The prototype has 58cm, and the second prototype shows 78cm. (Figure 14) The AngGo induces rotation by reducing the speed of rotations of the wheel located in that direction and increasing the speed of rotations of the opposite wheel. Since the rear wheel is an in-wheel motor, the caster, which is the front wheel, moves with force from the rear wheel's frame. The caster is not connected to the motor and steering-related devices. A caster whose wheel is rotated 360 degrees was used to align it for various driving. Therefore, it was judged that the essential point is how quickly and accurately the casters are aligned in the desired direction. First, to analyze the rotation, we analyzed the left and pure rotations. When rotating, the next rotation should be made due to the rotation speed difference on both sides of the rear wheel. The yellow dot in Figure 15 becomes the center of rotation at the beginning of the rotation, which requires rotation in a vertical direction in proportion to the front wheel's distance. (Figure 15)

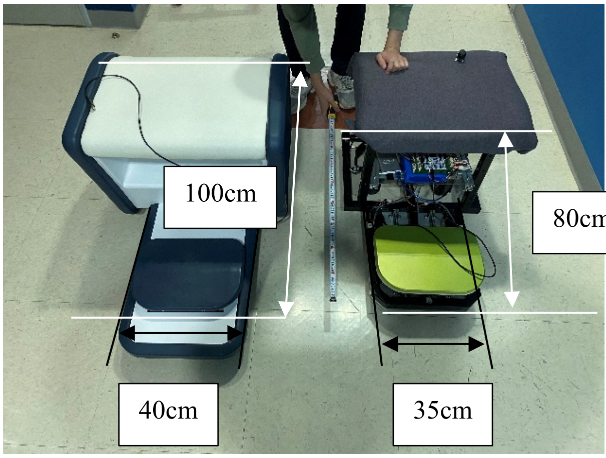


Figure 14. The first and second prototype (left: second prototype, right: first prototype)

In this way, as the distance between the front wheels increases, the speed required for the left front wheel decreases, and the right front wheel's speed increases. However, since the force exerted on the front wheel by the frame is relatively constant, alignment in the rotation direction is achieved after both samples have had a similar time. Therefore, it is expected that in the structure where the difference in speed required for the front wheels is severe, further repulsion will occur, and rotation, as desired, will not be achieved.

Another different factor of the two prototypes was wheelbase. The longer the wheelbase, the larger the turning radius. In other words, mobility should rotate at a larger angle. Therefore, the rotation radius becomes large, and the movement becomes dull. Therefore, driving can be difficult. Instead, it is advantageous for driving stability and ride comfort and has the advantage of good straightness due to increased inertia for going straight. However, because the turning radius is large, and the inertia goes straight, users may feel difficult and dull in driving. It also has the disadvantage of low turning ability. This can be supplemented by shortening the rear overhang.

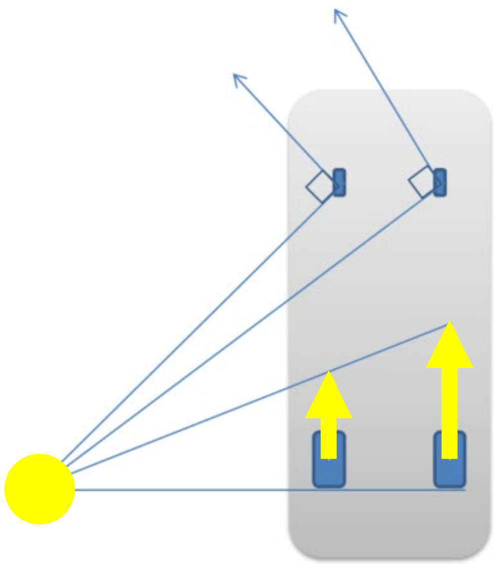


Figure 15. The speed induced in each wheel during rotation

Findings

The objective of the thesis is to create a SISM system. We devised, analyzed a seated platform, planned, manufactured the platform, and developed a prototype that implemented the configurations and desired functions of SISM. An observational experiment was carried out in the building's lobby or hallway to test both the autonomous mode. The AngGo platform moved in search of potential users and the manual mode, in which the rider drove it with a pedal plate. Based on this experiment's results, we established a set of optimized parameters and adjusted performance accordingly. Shared services have emerged as a means of using PMVs. More research is required to understand the optimum design of natural interaction, specifically for indoor contexts that leverage visual or auditory feedback. The natural interactions of AngGo, following and blocking, are studied from two perspectives: workload of input modality and useability of output modality. Results confirm that both the following and blocking methods exhibit insignificant workload differences. We then recognize that unimodal auditory feedback is less preferred, flattering, and comfortable over visual feedback and is less preferred and intuitive than visual-auditory bimodal feedback. The reaction time is shortened by unimodal auditory feedback. We suggest that natural interaction with the SISM vehicle can be improved by adding a visual modality, removing the risk of conflict, and informing whether an object is detected. Findings will contribute to the natural interaction design of service robots and shared PMVs considering an indoor context. The AngGo should be the compact size of wheelbase in autonomous mode for evading obstacles. To increase the drive experience of users, the longer wheelbase will be right. However, for autonomous mode, the shorter wheelbase is proper to dodge other obstructions.

Summary and Findings

1. Next-generation of AngGo should give robustness and safety experience to the user in design aspects. It should improve the riding experience, exterior material, and height.

2. Next-generation of AngGo should have a compact size for the autonomous mode in mechanical aspects. AngGo should be improved in terms of size, height, and wheelbase problem.

4
AngGo-N

- Design Features
- Three Types of Operating Mode
- Mechanical Structure
- Prototype Development Procedure
- Supplements and Findings During Development

4. AngGo-N

Design Features

AngGo-N is the Shared Indoor Smart Mobility platform, which helps users go to the designated destination by steering. The platform is intended to improve the efficiency of the time and energy of users. AngGo-N provides three types of operating modes. It usually requires self-driving to find the passengers. Alternatively, it could be a comfortable chair for users who needs rest. If a user wants to control mobility, they can also operate the AngGo-N with their foot. Therefore, switching is an essential part of use. We make a system diagram and sensors to discern between chair mode, control mode, and destination mode. Finally, we suggest foot steering as a new way of steering. We called it footstep steering because a user needs to step on the pedal plate to control the mobility. It might be a new steering system.

The lounge chair has made of plastic, wood, fabric, and leather. This material gives the user a soft feeling. The users use this chair for resting and recognize this as a comfortable thing. AngGo-N is SISM, which has dynamic characteristics. This has far different from static. To include the lounge chair, sofa's feeling in AngGo-N, we choose similar materials and functions with lounge chair. At the same time, we propose to use a different steering system to make a difference between SISM and electric scooters or electric wheelchairs.

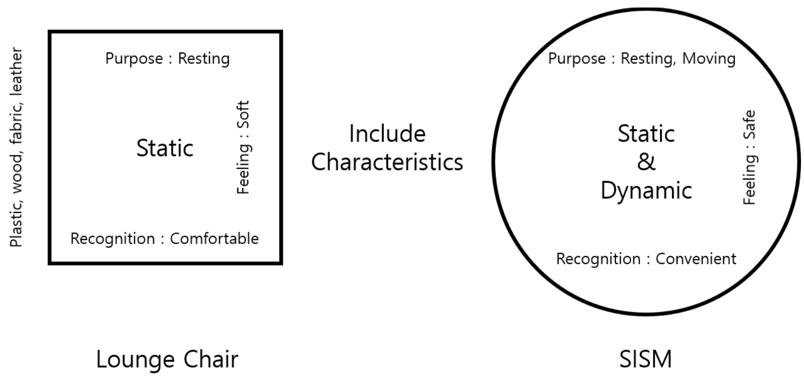


Figure 16. Features and Characteristics of the lounge chair and SISM

Aesthetic Mood Boards of the AngGo-N

In the workshop, we requested to select which mood will be preferred for SISM. These are selected mood board images by all participants. Extracted factors were applied to AngGo-N.

STK_01 by Pranab P Kumar

DAYBE SOFA by Luka Spasojevic

Vistic by Areum Gu

TimetoToast by Lee Sungwook

Coway FAB by OFFOF co

Smart Infant Carrier by ZAAFDesign

Beoplay home set by Bang and Olufsen

Black Pears by Dim Eysner

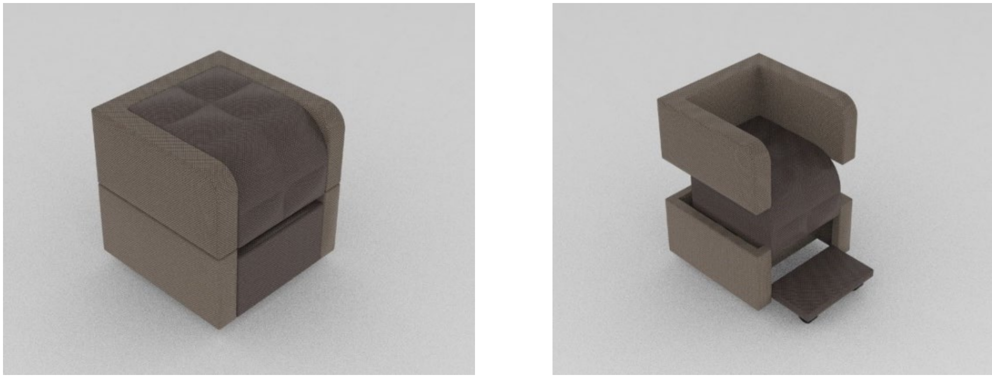
Figure 17. Design Mood board of AngGo-N

Concept Keywords of the AngGo-N

Compact; Reliability; Riding Experience; Soft; Indoor.

Concept of AngGo-N

The basic Concept of AngGo-N is giving comfort to users who board. AngGo-N has a compact size during the semi-autonomous driving mode. In this mode, AngGo-N finds other users indoors. When users about to ride AngGo-N, they sit in the center block. The center block seat parts are slightly going down, and the armrest, the backseat is coming up to support the user. Simultaneously, to make the wheelbase longer, the footrest part folded out to support the user's foot.



(left: the autonomous driving mode, right: the manual mode)

Figure 18. Concept Modeling of AngGo-N

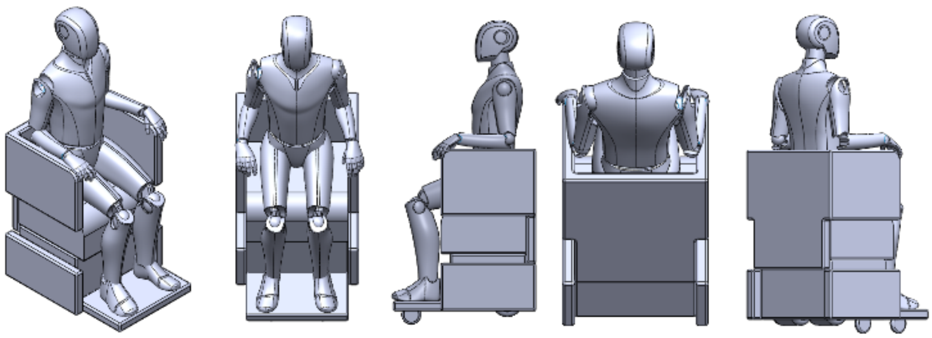


Figure 19. User Posture in use (User model height was 170cm)

Three types of operating mode

AngGo-N provides four types of operating modes. The modes can be changed by each other. First, Autonomous mode supports finding potential users to use AngGo-N. When AngGo-N and the user interact and recognize that a user will sit via voice, gesture, or action, AngGo-N enters Standby mode. In this mode, the user can sit and take a break on AngGo-N. When the user control AngGo-N with step pedal control, AngGo-N enter Journey mode. In Journey Mode, AngGo-N decides to enter standby mode or autonomous mode based on pedal control or seat switch (Figure 21).

As mentioned above, AngGo-N enables a user to select different modes. 6 ToF(Time of Flight) sensors are installed to detect obstacles and pedestrians. The general location of the ToF sensors is described in Figure 20. Each of the ToF sensors can detect 2 meters and have 27 degrees of Field of view(FoV).

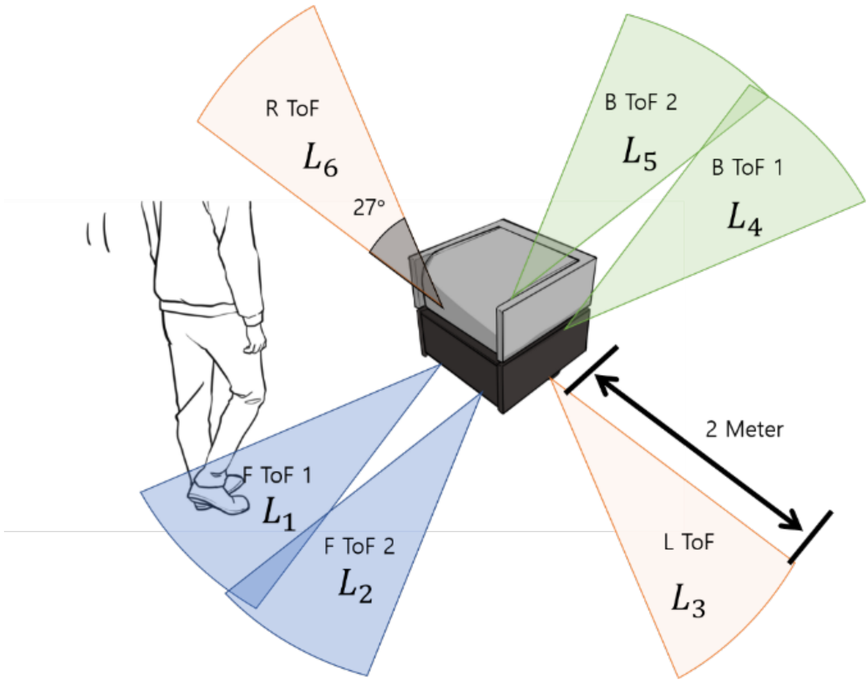


Figure 20. ToF description of AngGo-N

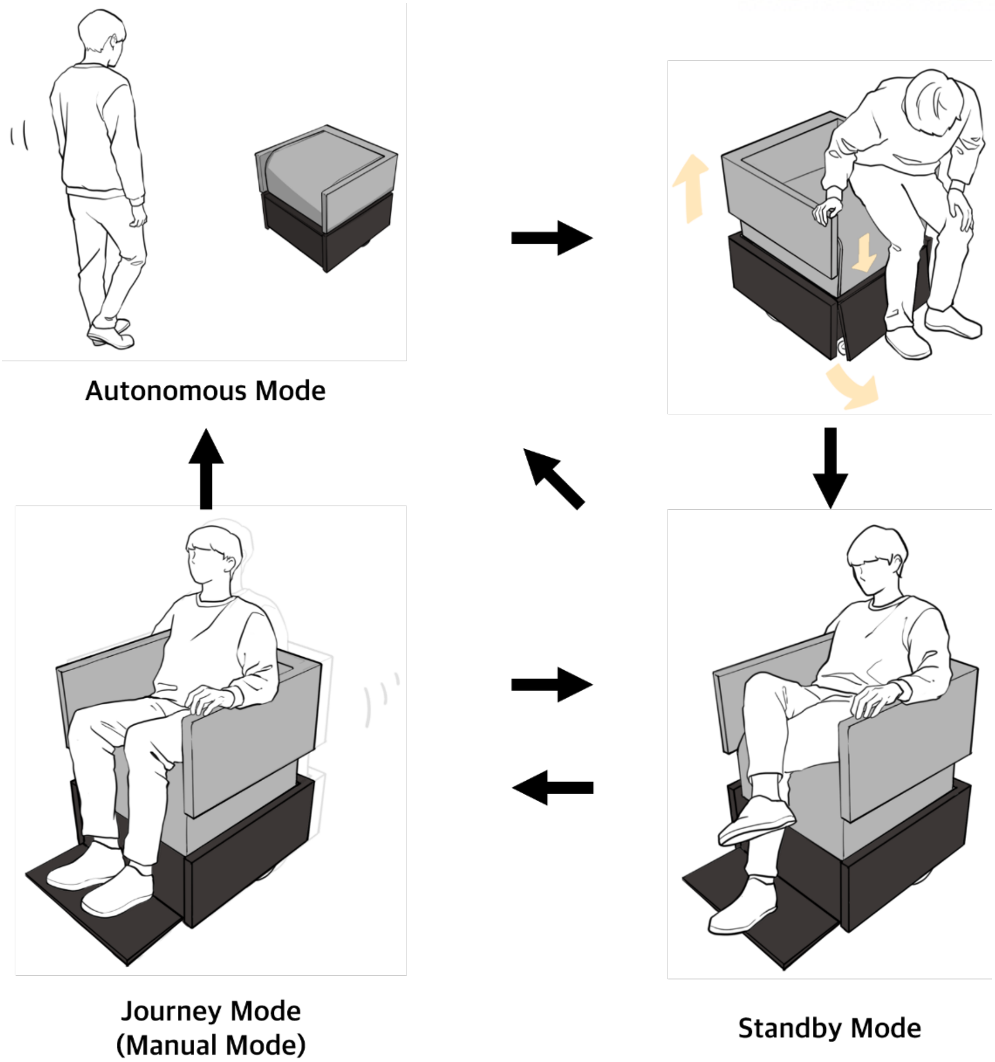


Figure 21. AngGo-N mode scenarios

Autonomous mode

In autonomous mode, as AngGo-N do Self-driving, the mobility moves around the lobby of the building and find potential users to use AngGo-N. If the batteries lower than a specific voltage, it automatically finds a charging station nearby. During autonomous mode, it could receive a request from another user to ride. If AngGo-N receives the request from users through the application, it travels toward the user. Before AngGo-N interacts with the user who sends the request, AngGo-N denies other user's interactions.

Standby mode

In standby mode, AngGo-N's in-wheel motor tries to stop. Users can ride on and take a rest or control the foot pedal. After user control or make an input on foot pedal panel, AngGo-N enter to manual mode. If the user inputs destination through application to AngGo-N, it enters to destination mode. When the user stands up from AngGo-N, the seat switch will recognize the user's absence. After a few seconds, AngGo-N enters Autonomous Mode.

Journey Mode

AngGo-N moves toward the destination, which is entered by the user who sits on mobility. AngGo-N moves through the pathway to the destination. During travel, AngGo-N avoids obstacles and pedestrians who are detected by 6 ToF sensors. Users sitting on AngGo-N can control mobility through a foot pedal plate. The distance of two feet of the user makes different input to two in-wheel motors. Steering of mobility is an important activity to ride on. However, for SISM, traditional steering is still insufficient. Mostly, there is no optimal standard way to control PMVs. We saw deep inside of steering way.

All traditional ways to control or steering mobility have strong and weak points to apply to SISM. In this paper, we follow the form of the sofa. Therefore, we consider relevant steering for AngGo-N with two feet. The most basic criterion criteria are from sitting sofa on AngGo-N. in this stable state. We consider new ways of steering mobility in the indoor environment. Finally, we can suppose step steering. Based on the foot control method, we apply a different control method for AngGo-N.

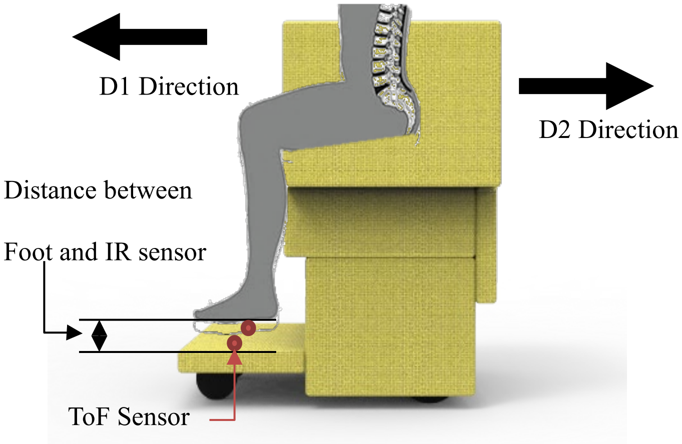


Figure 22. control method description

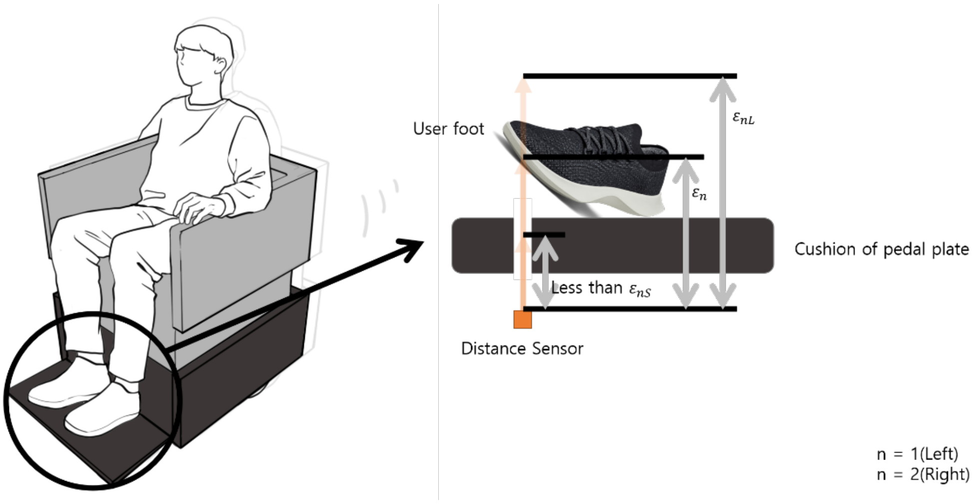


Figure 23. Distance sensor description

Two of the ToF sensors are located on the surface of the footplate in AngGo-N. ToF sensors measure the distance between the foot and the surface of the footplate. The distance information goes directly to in-wheel motor rotation speed. When calculating the value of a distance sensor at a given measurement location during a stopped state by ($\overline{S_n}$), and the value of the distance measured by S_n, then the distance change ratio (δ_n) required for motor output can be generated using (1) and (2). The equation is used for the left side motor drive unit (left side motor and right ToF) when n = 1 and for the right side motor drive unit (right side motor and left ToF) when n = 2. AngGo-N's movement follows (2) (See Table 2 and Figure 24):

$$\delta_n = \begin{cases} -1, & S_n < \varepsilon_{nS} \\ \dfrac{|S_n - \overline{S_n}|}{\mathrm{Max}|S_n - \overline{S_n}|}, & Ohterwise \end{cases} \tag{1}$$

where

$\delta_n \triangleq$ distance change ratio;

$\overline{S_n} \triangleq$ distance in the off state (cm);

$S_n \triangleq$ the distance measured by the sensor (cm);

$\varepsilon_{nS} \triangleq$ foot and ToF sensor distance threshold(short);

The AngGo-N determine to move or not based on the value of d_m. If this value is 1, AngGo-N moves. In the case of 0, AngGo-N determines to stop.

$$d_m = \begin{cases} 1, & \varepsilon_{nS} < \min(\delta_L, \delta_R) < \varepsilon_{nL} \\ 0, & \text{otherwise} \end{cases}, \tag{2}$$

Where

$d_{\mathrm{m}} \triangleq$ determination of movements;

$C_{\mathrm{s}} \triangleq$ motor stopping distance threshold;

$\varepsilon_{nL} \triangleq$ foot and ToF sensor distance threshold(long);

The control signal (P_n) for the motor drive unit that is operating the wheel motor is calculated by (3):

$$P_n = \gamma_n \delta_n \quad , \gamma_n > 0 \tag{3}$$

where

$P_n \triangleq$ motor control signal;

$\gamma_n \triangleq$ velocity control constant;

Table 2 and Figure 24 describe the movement of the AngGo-N equation. Value E is the experiment decided value that user press the foot pedal proper amount of weight to move D_2.

Table 2. AngGo-N manual mode example equation

	$\boldsymbol{\delta_1}$	$\boldsymbol{\delta_2}$
Stop	$E < \delta_1 < \varepsilon_{1S}$ or $\delta_1 > \varepsilon_{1L}$	$E < \delta_2 < \varepsilon_{2S}$ or $\delta_2 > \varepsilon_{2L}$
Move to D_1	$\varepsilon_{1S} < \delta_1 < \varepsilon_{1L}$	$\varepsilon_{2S} < \delta_2 < \varepsilon_{2L}$
Move to D_2	$\delta_1 < E$	$\delta_2 < E$
Turn clockwise	$\delta_1 < \delta_2$ where $\varepsilon_{1S} < \delta_1 < \varepsilon_{1L}$ and $\varepsilon_{2S} < \delta_2 < \varepsilon_{2L}$	
Turn counterclockwise	$\delta_1 > \delta_2$ where $\varepsilon_{1S} < \delta_1 < \varepsilon_{1L}$ and $\varepsilon_{2S} < \delta_2 < \varepsilon_{2L}$	

where $0 < E < 0.3$, $(n = 1, 2)$, (S = Short range, L = Long range)

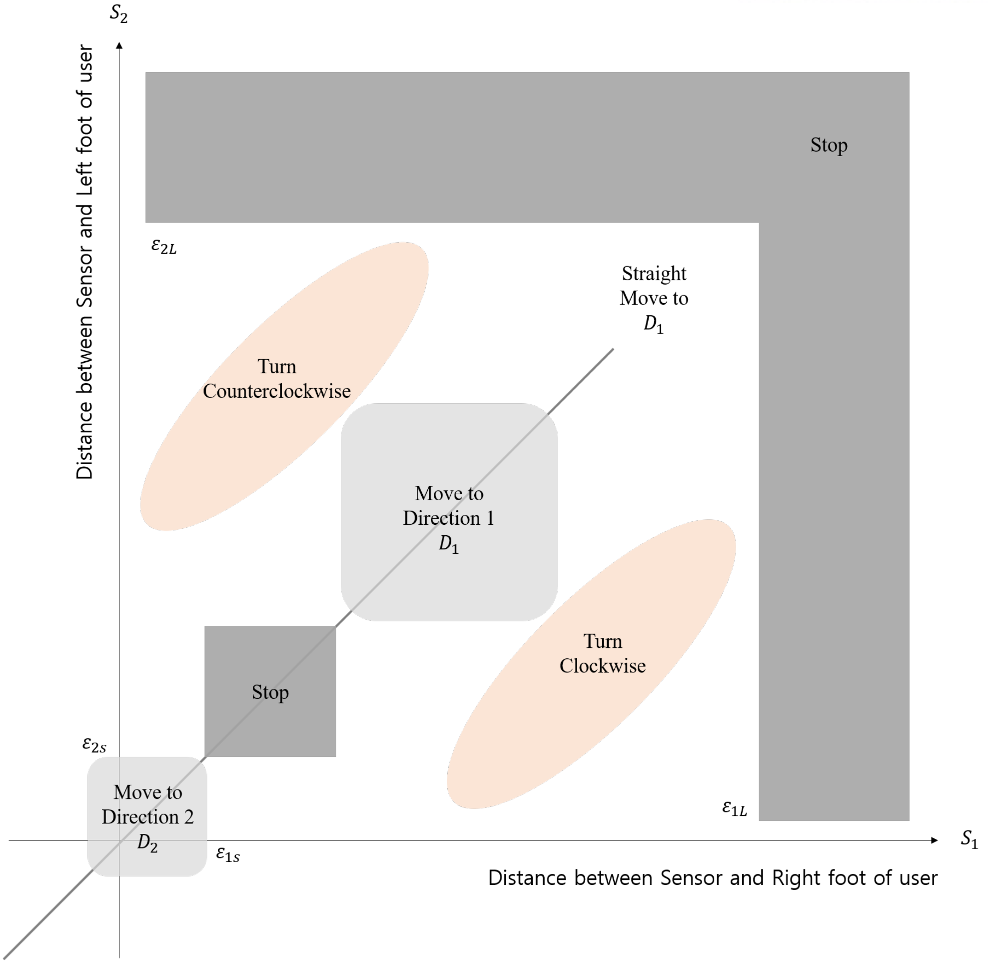


Figure 24. AngGo-N movement based upon the given equations

Scenario of AngGo-N

AngGo-N wanders around of stated inside of the building. When AngGo-N encounters a user who wants to use it, AngGo-N interacts with users, and the user sits down on the seat. When the user sits down, the seat part touches the seat switch of AngGo-N, and it tries to stop the fixed position by controlling two in-wheel motors. When the user interacts with AngGo-N, it moves as user input through pedal plates.

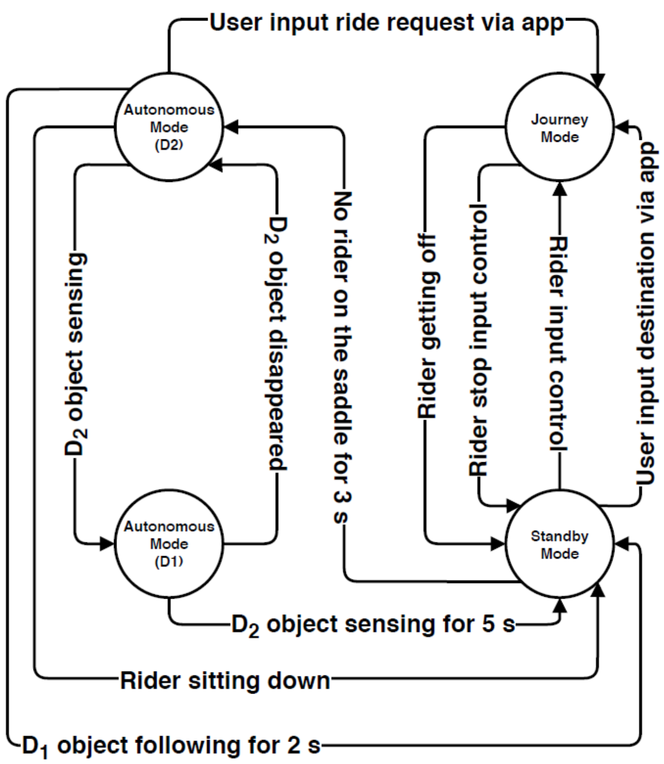


Figure 25. AngGo-N system diagram

Systems of the AngGo-N

The overall system follows AngGo's system (Figure 27).

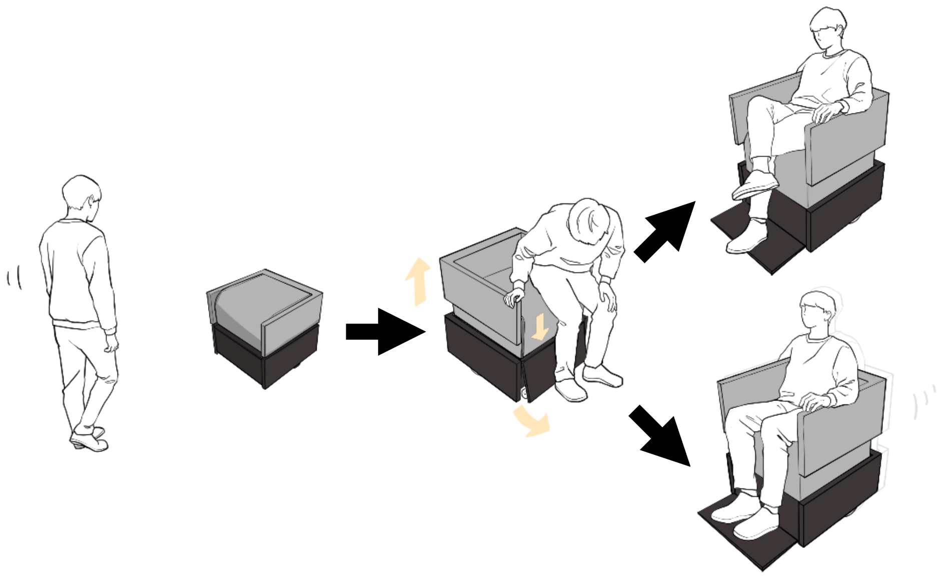


Figure 26. User scenario of using AngGo-N in the indoor building

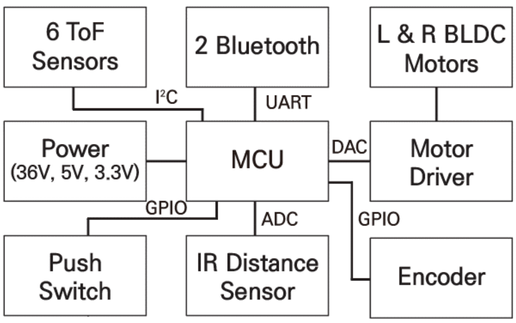


Figure 27. AngGo-N block diagram

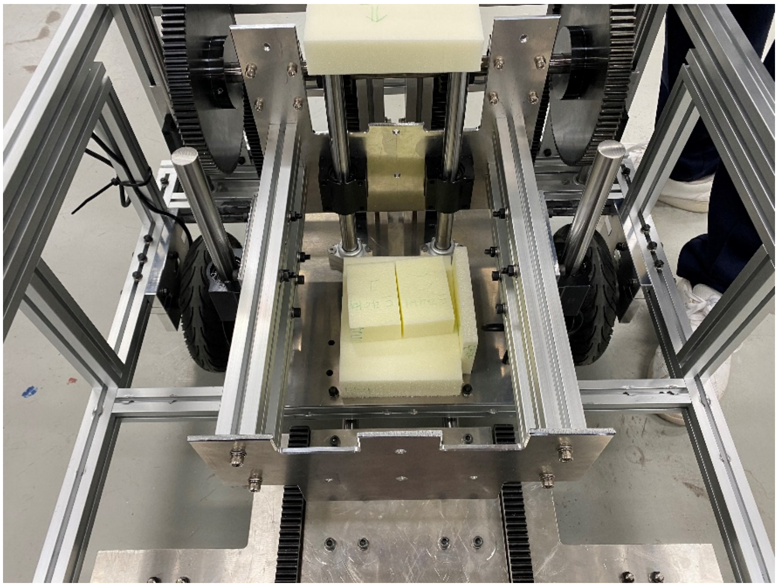


Figure 28. Implementation of electric components of AngGo-N in real size of foams

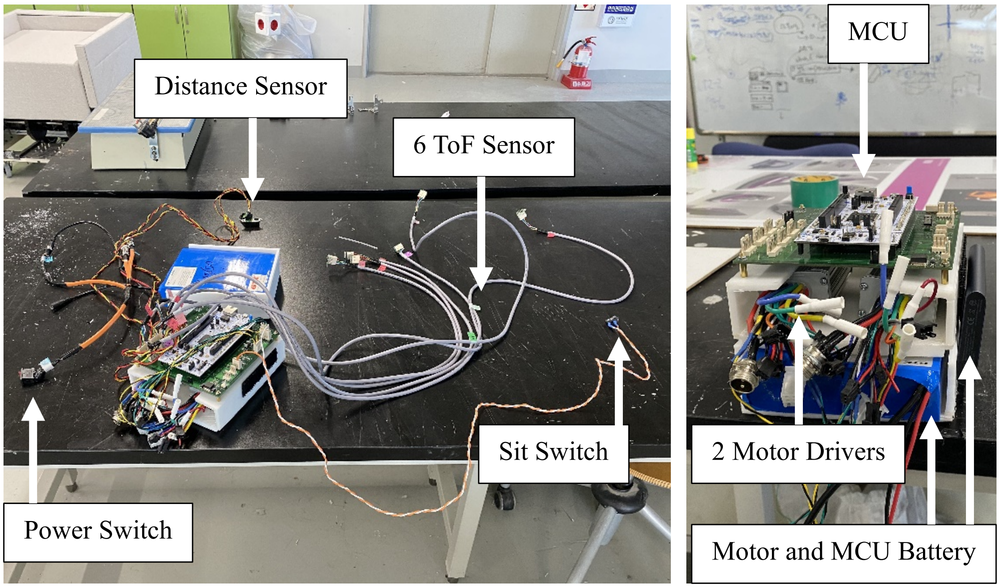


Figure 29. Implementation of electric components of AngGo-N

Mechanical Structure

AngGo-N has transformation aspects. Based on transformation design, we followed three conditions in papers. [35]

1. Transformable design can transform from one state with its functionality and physical form to another state with another functionality and physical form. Two or more of these individual states can exist.

2. Product transformation must be intended in the design process.

3. The deformation must be reversible, and the product is not separated.

Based on three conditions and interim results, we make the most compact aspects design in a box shape for testing outcomes of overall ideas.

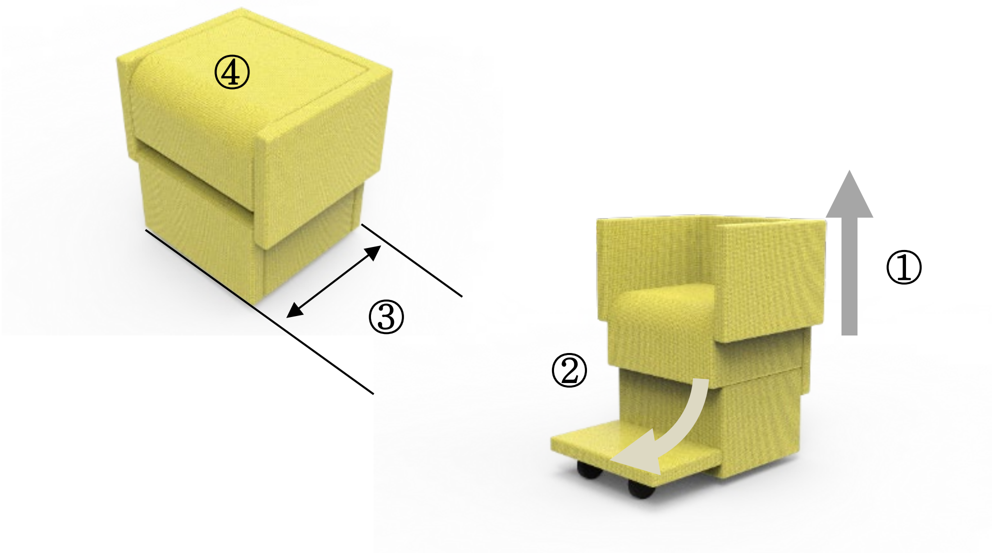


Figure 30. AngGo-N first mechanical concept model

① The back of the chair should exist at a certain height. We found various references in IKEA indoor and outdoor back of chair height and apply 75 cm from the seat.

② In moving personal mobility, the foot should be on the reliable plate. For the user, the front panel is folded out to support the footplate.

③ The wheelbase should be short of making the radius of rotation small. During autonomous mode, the front-wheel plate folded, and it makes the wheelbase shorter than manual states. In manual mode, a longer wheelbase enhances the driving experience than the short one.

④ The user's sitting posture to ride AngGo-N is similar to a sofa that users usually encounter in their living room or indoor. They could ride AngGo-N as they sit down on a usual sofa in front.

Mechanical Structure Analysis

AngGo-N is designed so that the backrest structure and footrest structure come up and forward, respectively, as the person's weight lowers the chair seat. There is a total of two parts, a gear structure that connects the seat and back structure and a gear structure that connects the seat and footrest structure. They are designed to increase the displacement compared to each gear's seat having a 1 to 5 radius ratio difference.

The minimum load to move the backrest structure was calculated by creating a force equation between the seat and the backrest structure. However, since the two gear parts have to rotate only by the seat's movement and move the footrest and the backrest, we will calculate by solving the force equation reflecting the relationship between the three parts.

First, since 20° is the industry-standard value for the normal spur gear pressure angle, it was assumed a pressure angle of 20° for all racks and pinions. Besides, AngGo-N consists of 4 parts in total: seat part (1), back part (2), footrest part (3), and body part (4), and these parts are the friction force between the rack and pinion and the floor (vertical drag). All forces except for are assumed to be zero. Finally, all structures were assumed to be parallel or perpendicular to each other. Each part was weighed using a force gauge.

Figure 31. Force gauge measurement

L ≜ Human weight

W_S ≜ Seat part weight =185N

W_B ≜ Backrest part weight =109.167N

R ≜ Radius of large gear

r ≜ Radius of small gear

F_{SB} ≜ The force between the small gear on the seat part and the rack on the body part

F_{SS} ≜ The force between the rack in the seat part and the small gear in the body part

F_{LB} ≜ The force between the large gear in the body part and the rack in the backseat part

F_{LF} ≜ The force between the large gear in the body part and the rack in the footrest part

f ≜ Friction force between the footrest and the floor=22.5N

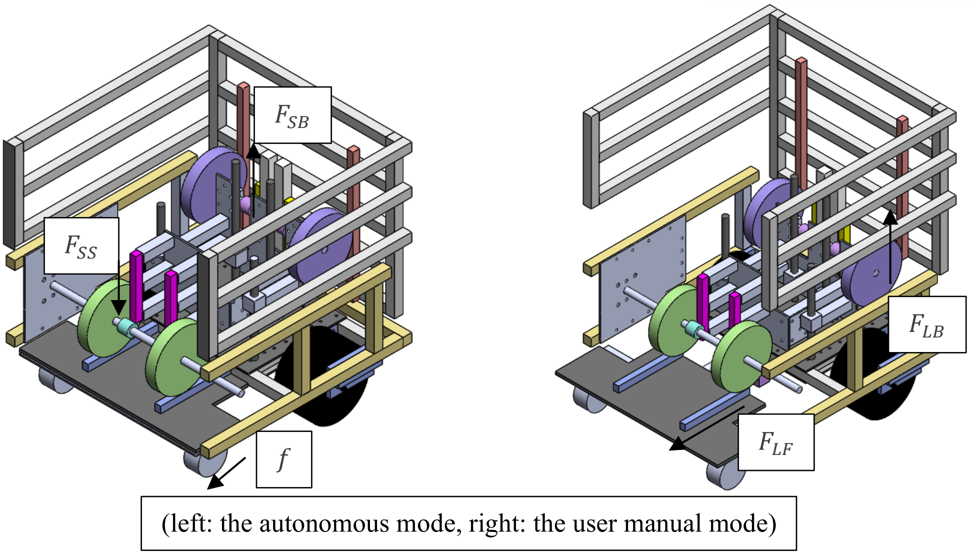


Figure 32. Equation definition description 1

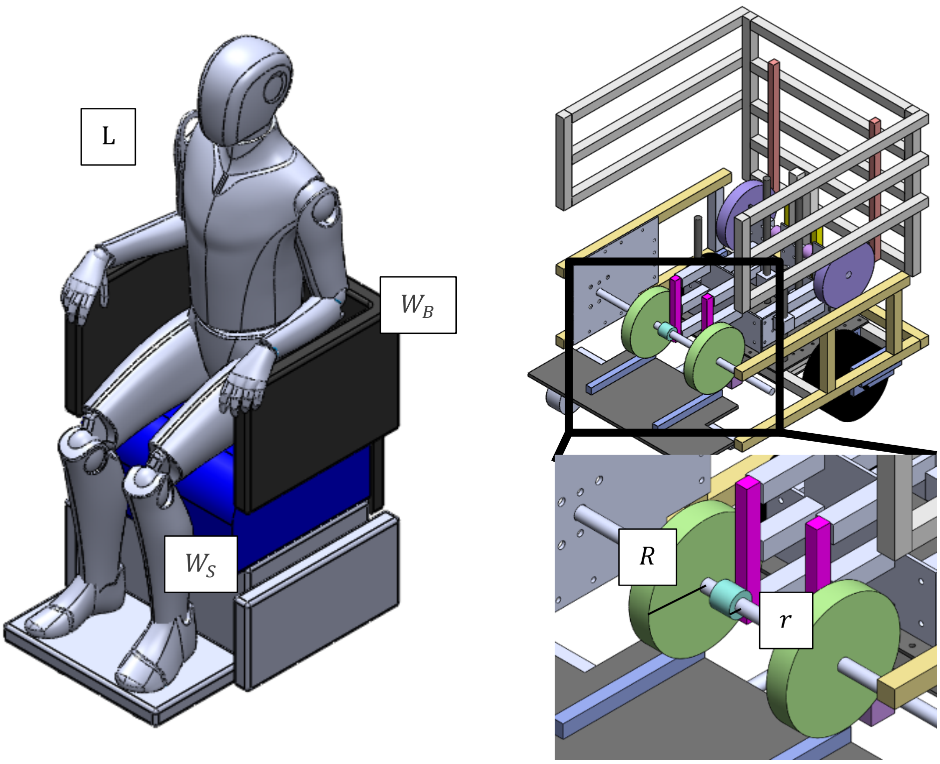
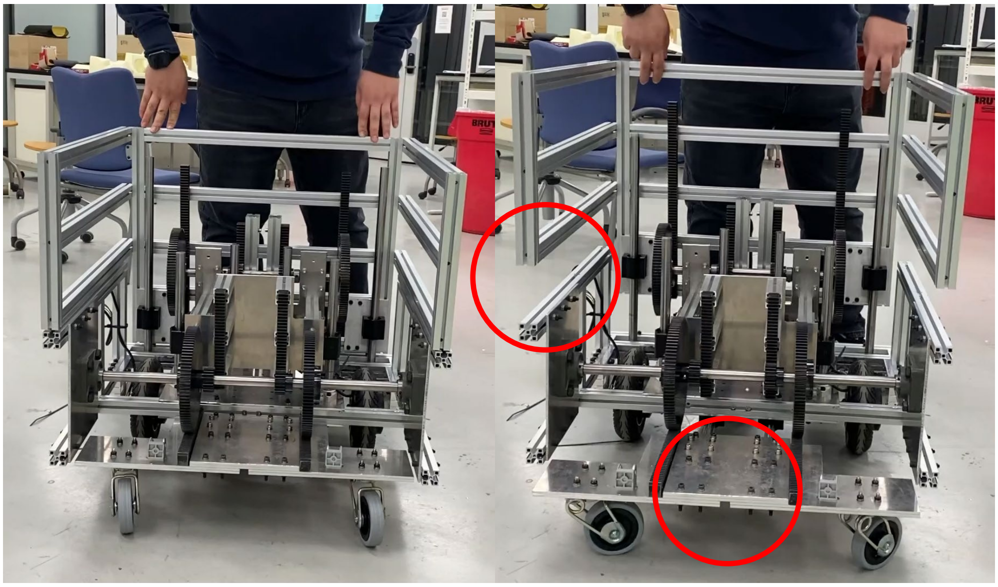
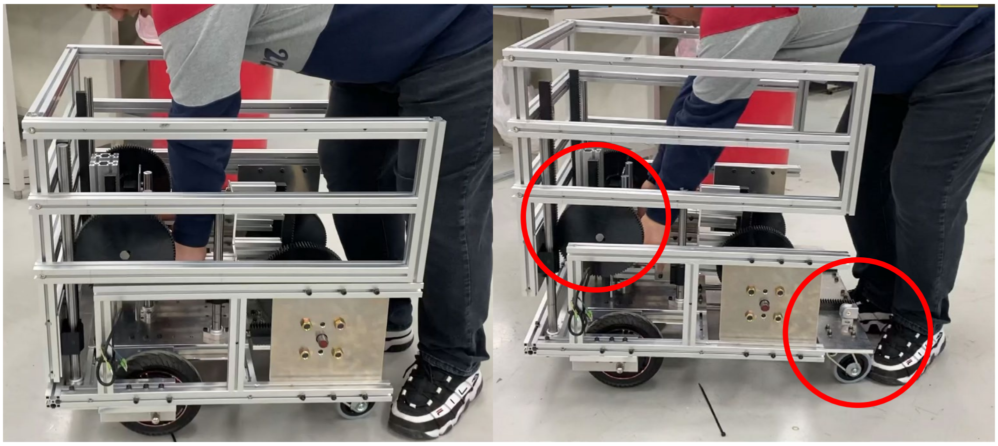


Figure 33. Equation definition description 2



(left: the autonomous mode, right: the user manual mode)

Figure 34. Structural change by sitting, front view



(left: the autonomous mode, right: the user manual mode)

Figure 35. Structural change by sitting, side view

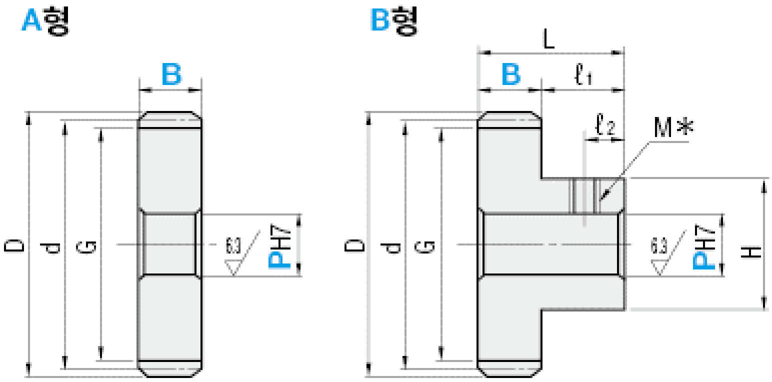


Figure 36. Gear Information [40]

form	*Module*	*Number of Teeth*	*Shaft hole diameter Ph7*	*B*	*Reference circle diameter d*	*End circle diameter D*	*Tooth root G*	*H*	*L*	*l1*	*l2*	*Allowable transmission power*
Small gear	2.0	22	8~25	20	44	48	39	36	34	14	7	29.21
Large gear	2.0	100	20~55	20	200	204	195	70	34	14	7	148.44

Figure 37. AngGo-N Gear Information Detail [40]

Moment equation of seat part gear axis,

$$F_{SB}R = F_{LB}r$$

Moment equation of body part gear axis,

$$F_{LF}R = F_{SS}r$$

Force equation of seat part y-axis,

$$-L - W_S + F_{SS}cos20 - F_{LB}\cos 20 + F_{SB}\cos 20 = 0$$

Force equation of Backrest y-axis,

$$-W_B + F_{LB}\, cos\ 20 = 0$$

Force equation of pedal part x-axis,

$$-F_{LF}\ \cos 20 + f = 0$$

Force equation of Body part y-axis,

$$-F_{SS} cos\ 20 - F_{SB} \cos 20 + N = 0$$

Based on Figure 37,

$$R = \left(\frac{200}{44}\right) r = 4.55r$$

$$f = F_{LF}\ \cos 20 = 0.22\ F_{SS}\ \cos 20$$

$$W_B = F_{LB}\ cos\ 20 = 0.22\ F_{SB}\ \cos 20$$

$$L + W_S = F_{SS} cos 20 - F_{LB} \cos 20 + F_{SB} \cos 20$$

$$= 4.55f - W_B + 4.55W_B$$

$$L = 4.55f + 3.55W_B - W_S = 4.55(22.5) + 3.55(109.167) - 185 = 304.917\ [N]$$

As a result of the force gauge experiment, L came out as 440N, and there was a difference of 135.083N. This error is due to the use of an ideal assumption. It is assumed that it is due to several reasons, such as frictional force with the pipe when gear part and rack movement.

Prototype Development Procedure

With real size structure and information in IKEA and Size Korea, we make a frame of AngGo-N. Up and down motion was held by the current chair and finalized the frame's size, including exterior panel thickness. To reinforce the aluminum profile, we cut an aluminum plate and attach each part. (Figure 38) After deciding the frame's exact size, we make an initial frame and attach a guide pole for the backrest and foot pedal parts. (Figure 39) At the same time, the rear overhang was too long for mobility. Within the structure, we made a new fork for an in-wheel motor fork with an aluminum plate. (Figure 40) two of the fork parts consist of a joint structure that makes the fork hold the structure and in-wheel motor simultaneously.

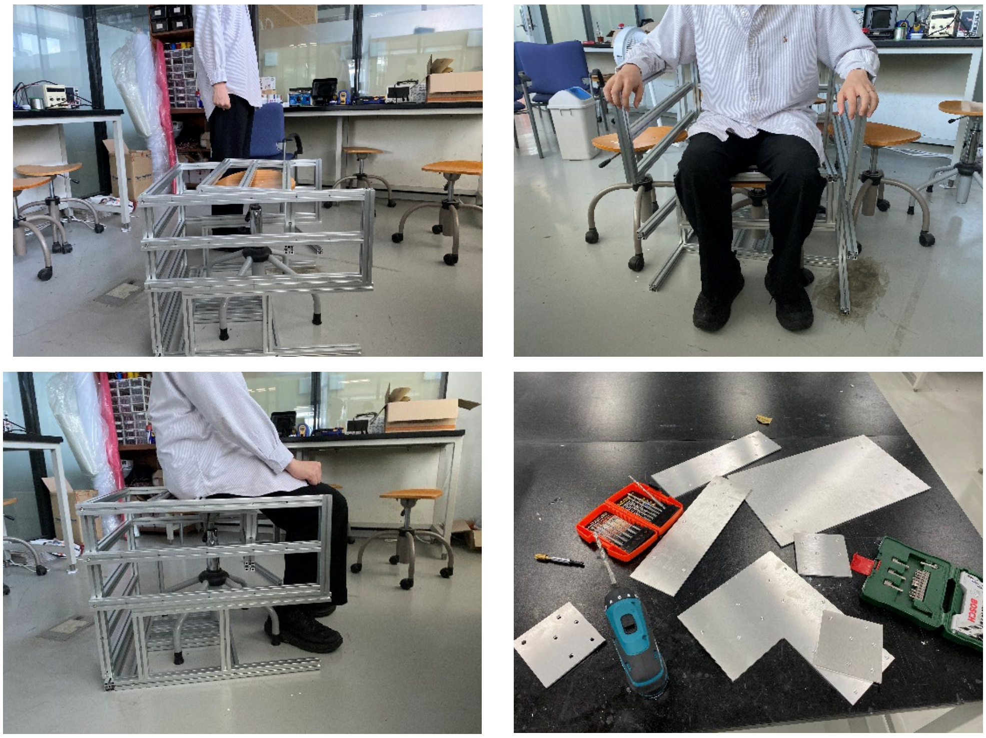


Figure 38. User test in real size model prototype

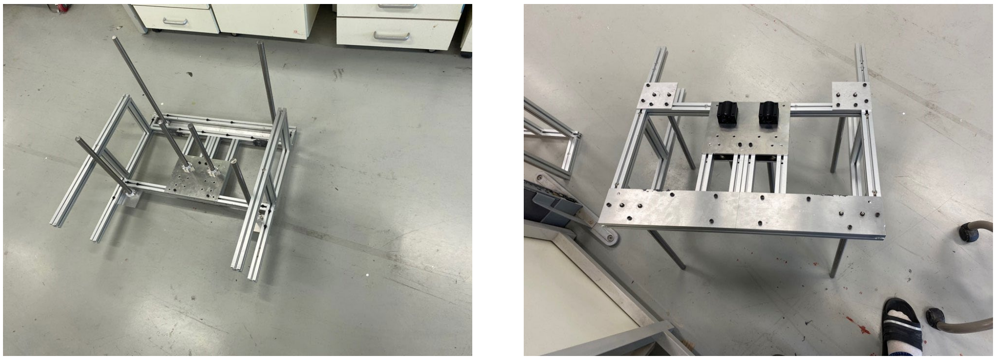


Figure 39. the initial stage of the frame

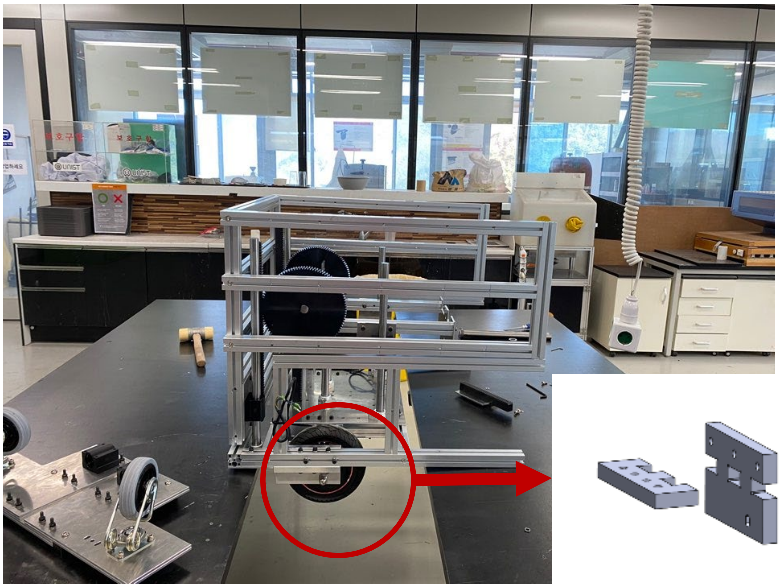


Figure 40. Reinforced wheel fork of AngGo-N

Exterior Design Procedure

The exterior design part consists of a wood panel. The backrest part was covered with fabric cover on the wood plate. Each wood plate was treated with stain and varnish. After drying all plates, each plate is attached to the frame of AngGo-N (Figure 44). Seat parts of AngGo-N have consisted of two parts. One of the seat parts is for fastening the cushion and body frame of AngGo-N. The second seat part has fabric to give a cozy feeling to the user (Figure 45). For colors of AngGo-N are decided based on the combination of the axis of wood parts and fabric parts (Figure 41). The fabric has a similarity with the materials used on the sofa. Wood parts were processed by stain chemicals (Figure 44). Dual lock tape makes the frame and exterior plates stick together. The seat parts were consisting of two different parts. One for hold frame with seat load distribution part, and another part hold cushion of the seat (Figure 42, Figure 43).

Figure 41. First form iteration process of AngGo-N

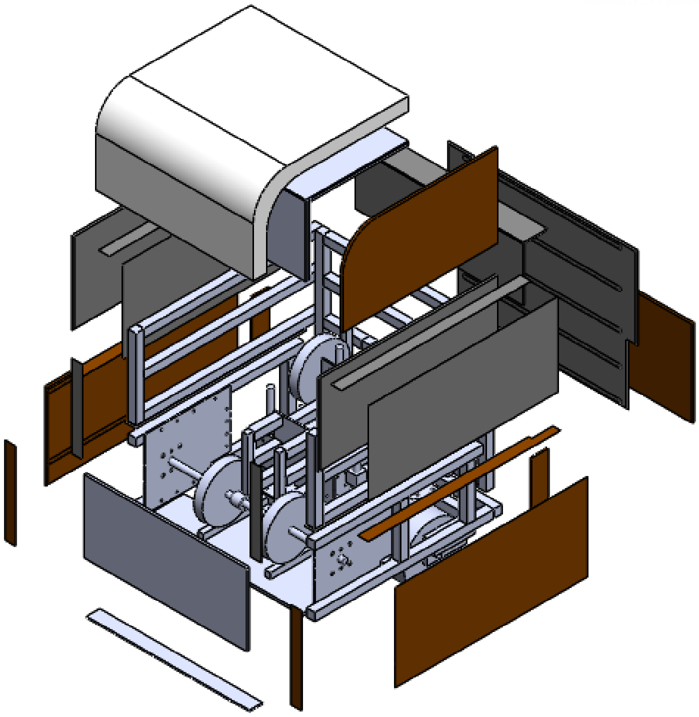


Figure 42. Exploded image of AngGo-N

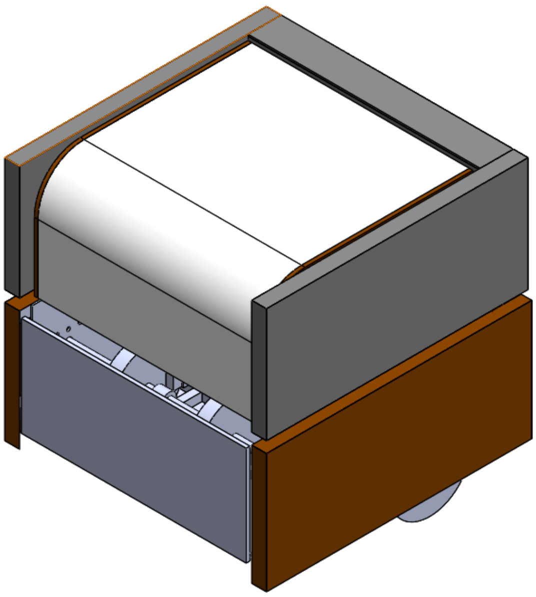


Figure 43. Assembled image of AngGo-N

Figure 44. Fabricating process of Exterior plates

Figure 45. Parts assemble process

Seat Part Assemble

The seat part will encounter the user's weight and gear movement. To make sure this all part work smoothly, we attached six compartments to joint body and seat part. On the top of the seat part, we attached a 50mm sponge to give the user a comfortable feeling about AngGo-N. Before we assemble sponge and fabric parts, we make a structure to make forms in a specific area. All the shapes were in a box shape, and we give two brown side plates to give users intuitively know the seat part area. The seat compartment size was coming from the IKEA sofa seat size.

Figure 46. Seat Parts assemble process

AngGo-N prototype

The outcome of the prototype is in Figure 47. Within the indoor environment, it gives a similar feeling to the lounge chair. Exterior plates hide two casters and in-wheel motors. The raised backrest makes the assistant elbow rest part elevate together. At the same time, the footplate holds the user's foot. Users can hold or lean to one of the compartments to rest on SISM mobility. After the rider gets off SISM mobility AngGo-N, all the compartment goes down and folds to become the square shape of AngGo-N.

Figure 47. A finished prototype of AngGo-N(Autonomous mode)

Figure 48. AngGo-N finished prototype (Standby and Journey Mode)

Supplements and Findings During Development

Mood board supplements

On the mood board, the product phenomenon, appearance, and feeling must be connected by a form factor. All factors that affect the product have to be segmented by problem definition, user investigation, and analysis. Based on segmentation, design requirements are coming out. Functional requirements are related to function and performance. Ergonomic(useability) requirements are relevant to usability, and symbolic requirements are related to the appearance, sense, and feeling of products. The functions and performance make the specification of products. Based on target analysis, the metric and volume came out. Functional requirements are solved by structure and technical improvement. Ergonomic requirements have consisted of convenience, interface, and interaction of products. Symbolic requirements make a proper aesthetic appearance and CMF related to the target or class of users. Here mood board or imageboard can be applied to the product development procedure(Table 3).

Target Analysis

It should have been decided who is the target user of AngGo-N. The specific target users' needs to be investigated. It needs to set a target, keywords, and concepts. Based on target analysis, the overall shape, detail features, and CMF can be matched with target and AngGo-N.

Table 3. Requirements of personal mobility

	Requirement	Specification	Metric	Volume	Reference
Functional Requirements	Personal mobility is transformed based on target users' height and weight.	Height	cm	168.5	[45]
		Weight	Kg	64.3	
Ergonomic Requirements	When a user approaches mobility, it must stop.	Distance between the user and personal mobility	cm	75	-
Symbolic Requirements	Have a modern look and match the interior.	Mood Board Form Factor CMF	-	-	[44]

5

AngGo & AngGo-N

Concept and Platform Comparison of Two Model

- Main Research Questions
- Expected Contribution

5. AngGo & AngGo-N

Main Research Questions

Our primary research question was to know 'how to improve the acceptance of the SISM?' and 'what is the needed design implication of SISM?'. We have developed AngGo and AngGo-N to research the possibility and functional aspects of usual users to know this central research question. We will go through competitive testing and value opportunity analysis about two platforms with two developed personal mobility.

Competitive Testing and Value Opportunity Analysis

All the experiments were held in the safety area, did not restrict other pedestrians by caution, or installed warning signs during the experiment. The AngGo-N and AngGo were placed, and all the participants to be a user and pedestrian. This makes participants fully understand and pre-step to give value Opportunity analysis after that. The form of experiments is based on competitive testing [25]. This is the process of researching to evaluate the useability and learnability of competitors' products. [39] The process of AngGo and AngGo-N includes monitoring participants. We want to know the opportunity to assess two SISM platforms from the end user's point of view through competitive testing. All participants were recruited from significant design students or related. We let all participants be aware of the potential for bias between two platforms. After participants use two platforms, we tracked and compared the interaction and reaction of them. Competitive testing results include insights from competitive platforms, and these results were collected through Value Opportunity Analysis. Value opportunity analysis maps the extent to which a products' aspirational qualities align with people's idealized lifestyle or a fantasy version of themselves[39]. This experiment proves with a list of value-based criteria or value opportunities. There were seven value opportunities, and we revised them to fit two SISM platforms in six lists. In emotion criteria, 'adventure, independence, sensuality, confidence, and power.' Aesthetics case, 'visual and tactile' was selected. Identity has 'point in time, sense of place, and personality. For ergonomics, 'comfort, safety, and ease of use' were asked. In the last criteria, quality has 'craftsmanship and durability' listed. The instructor discussed all the listed words' exact meaning in this experiment to make the same understanding between them [26].

Seven Value	Attributes	Meaning
Emotion	Adventure	The product promotes excitement and exploration
	Independence	The product provides a sense of freedom from constraints
	Sensuality	The product provides a luxurious experience
	Confidence	The product supports the user's self-assurance and promotes his or her motivation to use the product
	Power	The product promotes authority, control, and a feeling of supremacy
Aesthetics	Visual	The visual form must relate shape, color, and texture to the context of the product and the target experience
	Tactile	The physical interaction of the product, primarily focusing on the had but also including any other physical contact between the product and user, must enhance the product experience
Identity	Point in time	In order for a product to be successful, it has to capture a point in time and express it in a clear, powerful way. Point in time is a tricky combination of features and aesthetics
	Sense of place	Products must be designed to fit into the context of use
	Personality	The two main issues in a product personality are 1) the ability of a product to fit among yet differentiate itself from its direct competition, and 2) the connection that a product has to the rest of the products produced by that company
Impact	Social	A product can have a variety of effects on the lifestyle of a target group, from improving the social well-being of the group to creating a new social setting
	Environmental	The effect of products on the environment is becoming an important issue in terms of consumer value. Design for the environment, or "green design" focuses on minimizing negative effects on the environment due to manufacturing, resource use of the product during operation, and recycling
Ergonomics	Comfort	Along with ease of use and safety, a product should be comfortable to use and not create undo physical or mental stress during use
	Safety	A product must be safe to use. Moving parts should be covered, sharp corners eliminated, and internal components shielded from users
	Ease of use	A product must be easy to use from both a physical and cognitive perspective. A product should function within the natural motion of the human body. The ergonomics of the size and shape of components that a person interacts with should be logically organized and easy to identify, reach, grasp, and manipulate.
Quality	Craftsmanship	The product should be made with sufficient tolerances to meet performance expectations
	Durability	The craftsmanship must hold up over the expected life of the product

Figure 49. Value opportunity analysis meaning [26]

After Competitive testing, all participants were asked to answer this questionnaire. This method is one of the best uses for the VOA to measure how our product stacks up to competitors' products in terms of perceived value to the audience [39] (Figure 50).

All interviews were conducted through a google questionnaire. The participants only enter their code to distinguish between them and input what they experienced.

Expected Contribution

AngGo and AngGo-N were born based on design process and experiments to know acceptance of SISM concept and platform to usual users. We expected that this research question and experiment verify the needs of SISM and the primary form of sit type platform for SISM.

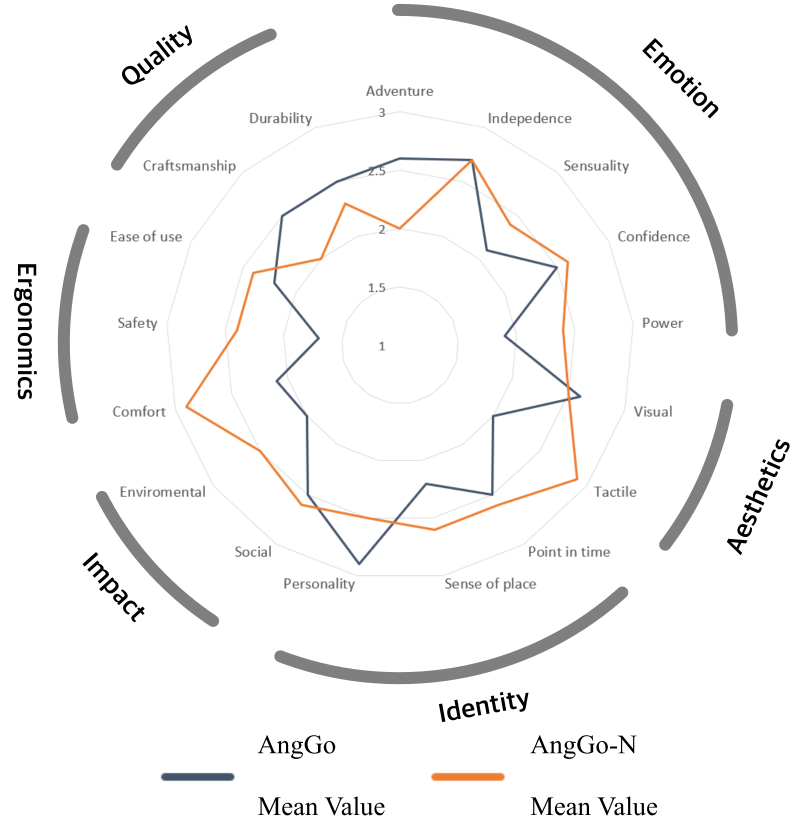


Figure 50. value opportunity analysis for SISMs answer mean value and criteria

6

Discussion

Important Factors in SISM

- Discussion
- Further work and Limitation

6. Discussion

A detailed discussion about answers of value opportunity analysis

Figure 51. value opportunities score criteria mean scores

Figure 52. Re-align value opportunity analysis score of two platforms

We filtered based upon criteria that AngGo-N and AngGo. Participants give a high score to AngGo-N with Tactile, Comfort, Environmental, Safety, Power, Sense of Place, Point in time, Confidence, Social, and Sensuality. AngGo has a high score in Adventure, Visual, Personality, Craftsmanship, and Durability. In the independence criteria case, AngGo and AngGo-N have the same score.

The answer to Two Research Question

RQ1: How to improve the acceptance of the SISM?

For improving the acceptance of SISM to users, we added indoor factors in material and finishing. We added wood and fabric materials to cover the surface of AngGo-N. At the same time, we added more soft filling to the seat part. Answers from research participants follow the AngGo-N's result of aesthetic and ergonomic factors getting a higher score than AngGo. Based on this result, to improve the acceptance of SISM to users, developers of SISM have to use the material and finishing related to indoor aspects. To improve the acceptance of SISM, the design also has to be a similar object that already existed in the indoor environment. In AngGo-N's case, we utilized the characteristics of a sofa and designed a mood board. These aspects affect AngGo-N to get a higher value than AngGo in aesthetic, ergonomics, and impact criteria. In three criteria, Visual, Tactile, Social, Environmental, Comfort, Safety, and ease of use were listed. Users can accept more on SISM when the platform looks like similar or familiar objects related to indoor.

RQ2: What is the needed design implication of SISM?

SISM is close to users in moving indoor environment space. For increasing users' acceptance of AngGo-N, we interpret past interviews and experiments in other papers. After that, we ran through interviews with developers of AngGo. We added a cozy feeling with wood and fabric-covered plates in AngGo-N. In the user study, we settled AngGo and AngGo-N in the same space to see participants' interaction toward two SISM platforms. Keywords and factors that we extracted from interviews are identity and emotion criteria. Two platforms got similar scores. However, the two platforms' form and material are far different from each other. First, Design implication aspects have to be considered in time, sense of place, personality, adventure, independence, sensuality, confidence, and power when making SISM platforms. Second, if the form and material are similar to indoor related objects, the user can accept more on SISM. The AngGo exterior platform was made of curved plastic and leather and looked & feel far different from indoor objects. This made AngGo's and AngGo-N's user acceptance differently.

Moreover, AngGo-N already settled users' hands, body, back, and feet. SISM platforms have to consider all of the body compartments to settle in specific places, not to force or compel the users to do certain positions. This can be done by adding design implications in the design stage, considering users' actions and posture when users operate the SISM platform.

Further Work and Limitation

The weight of AngGo-N is too heavy. It needs an optimization process in components weight. It could be merged frame with reinforcement plates. If increasing of AngGo-N weight succeeded, the available time of motor could be increased.

Experiment space is too narrow for the definition of Shared Indoor Smart Mobility. SISM concept could be applied much more prominent place, like convention centers or airports.

AngGo has passed through the experiment of light and sound interaction. However, AngGo-N needs more experiment and research about interaction users and AngGo-N's lights and sounds. Personal mobility for indoor purposes should have additional feedback to interact with pedestrians and drivers. This can contribute to the SISM maker to consider these aspects while they design personal mobility exterior. Considering personal mobility for the indoor purpose should have different cues in interacting between pedestrian and driver, the findings can help carmakers better design their indoor personal mobility to increase the drivers and pedestrians' satisfaction.

It is needed to investigate how much impact the transformation has. Furthermore, due to the change in shape, additional research is needed on how transformable design fits well with the mode change of personal mobility.

7
Conclusion
transformable personal mobility providing autonomous and manual driving mode

· Conclusion

7. Conclusion

This study set out to investigate how to design and implement SISM(Shared Indoor Smart Mobility). To research, these research questions were constructed: How is the acceptance of the indoor PMVs? What is the needed design implication of indoor personal mobility? We designed AngGo-N to reinterpret AngGo in user's needs. We significantly considered how the design could be blended into PMVs in the indoor environment during the design processing. To investigate the two research questions, we deployed AngGo and AngGo-N in the indoor building hallway. We run competitive testing and value opportunity analysis. Within the period, we observe ten experiments that participants use AngGo and AngGo-N.

For this study, we derived the new concept of SISM through AngGo. We applied insights derived from AngGo's useability test, interview, and mechanical review to AngGo-N. Simultaneously, we could confirm that AngGo and AngGo-N raised users' acceptance for SISM devices to be positively conscious of their movement in indoor space and shared mobility concept. There are many suggestions that this study can make to improve SISM. First, we defined SISM based on AngGo, and make new aspects of design. AngGo-N is the Shared Indoor Smart Mobility in the form of a chair. Moreover, we discovered opportunities to answer two questions, 'How to improve the acceptance of SISM?' and 'What is the needed design implication of SISM?'.

Finally, we hope this thesis to be a helpful step for further development and investigation on the topic of the SISM, as there is not much existing literature regarding design aspects and acceptance of the indoor driving aspects.

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Appendices

Raw data of Answers From Value Opportunity Analysis

	Test object	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N	AngGo	AngGo-N
	Participant code	KSB	KSB	KBH	KBH	PSY	PSY	KYJ	KYJ	MG	MG	PHE	PHE	RYD	RYD	KJY	KJY	LJY	LJY	LSH	LSH
Value Opportunity																					
Emotion																					
Adventure		2	1	3	2	2	2	1	2	3	2	3	2	3	2	3	2	3	3	3	2
Indepedence		3	3	3	2	2	2	2	2	3	3	3	3	2	3	3	3	3	3	3	3
Sensuality		2	2	2	2	2	2	2	2	3	2	2	3	2	3	2	3	2	2	2	3
Confidence		3	2	2	3	3	3	2	3	3	3	2	3	2	3	2	2	3	1	3	3
Power		2	1	1	3	3	3	2	3	2	3	3	2	1	2	2	1	2	3	1	3
Aesthetics																					
Visual		2	2	2	2	3	3	3	3	3	2	2	3	2	3	3	3	3	1	3	3
Tactile		2	3	1	3	2	3	2	3	3	3	1	3	2	3	2	2	2	3	3	3
Identity																					
Point in time		3	3	2	3	3	3	2	2	3	2	2	3	2	2	2	3	3	2	3	3
Sense of place		2	3	2	3	2	1	2	3	3	3	1	3	3	3	2	2	3	2	2	3
Personality		3	3	3	2	3	2	3	3	3	2	3	2	3	3	3	2	2	3	3	3
Impact																					
Social		3	3	2	2	2	2	2	3	3	3	2	3	3	2	2	3	3	3	3	2
Enviromental		3	3	2	3	2	2	1	3	3	3	1	3	2	2	2	2	1	1	3	3
Ergonomics																					
Comfort		2	2	2	3	1	3	2	3	3	3	3	3	2	3	2	3	2	3	2	3
Safety		3	2	1	2	2	3	1	2	2	2	2	3	1	3	2	1	2	3	1	3
Ease of use		2	3	2	1	1	3	2	2	2	2	3	3	2	3	3	1	2	3	3	3
Quality																					
Craftsmanship		3	1	3	1	2	1	2	3	3	3	3	2	3	2	2	2	2	2	2	3
Durability		3	1	2	2	2	3	3	1	3	3	2	3	3	2	2	2	2	3	3	3

Executive Summary in Korean

이 논문은 AngGo-N 이라는 사용자와 상호작용이 가능한 가변형 Shared Indoor Smart Mobility 장치의 개발에 대해 설명합니다. 개발 과정에서 PMV (Personal Mobility Vehicles)와 AngGo 에 대한 연구와 연구를 수행했습니다. AngGo 는 실내 이동이 필요한 잠재 사용자를 찾는 실내 개인 이동성입니다. 이 졸업 논문에서 목표는 새로운 인터랙션 요소를 가진 Shared Indoor Smart Mobility 를 개발하고 AngGo-N 이 사용자 요구 사항을 실질적으로 충족하도록하는 것이 었습니다. 이 연구는 공유 실내 스마트 모빌리티가 실내 환경에 대한 운송 사용자의 니즈를 어떻게 충족시킬 수 있는지에 기여합니다. AngGo-N 을 개발하기 위해 두 가지 연구 가설을 설정했습니다. 첫 번째는 'SISM 수용도를 높이는 방법' 입니다. 두 번째는 'SISM 의 설계에 사용자가 필요로 하는 인터랙션의 니즈는 무엇입니까?' 입니다. AngGo 의 문제점을 바탕으로 해결책을 찾아서 AngGo-N 의 디자인에 적용했습니다. AngGo-N 에 변형 가능한 요소를 적용하여 사용자와 개인 이동성 간의 상호 작용을 제공했습니다. AngGo-N 은 사용자에게 자율 모드와 사용자 제어 수동 모드에서 다양한 형태를 제공하고, 이를 통해 사용자와 인터랙션 합니다. 만들어진 AngGo-N 의 프로토 타입을 바탕으로 Value Opportunity analysis 와 Competitive Test 를 실시했습니다. 마지막으로, AngGo-N 과 같이 가변 형태의 퍼스널 모빌리티가 사용자와 어떠한 인터랙션을 하는지, 기존의 방식들에 비해 어떤 효과를 가지고 있는지에 대한 추가적인 논지를 제시합니다.

핵심어: 퍼스널 모빌리티, 실내 공유형 스마트 모빌리티, 가변 형태를 가진 모빌리티

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우선 저의 부모님 두분과 동생에게 감사하다는 말을 올립니다. 석사 과정에 진학하고 많은 고난의 시간동안 버티고 힘을 내게 해 주셨습니다. 참 스승님이자 많은 지식과 노하우를 전수해주신 이희승 교수님. 언제나 동반자처럼 함께 문제점을 고민하여 주시고 때로는 먼저 올바른 길을 지도해 주셔서 석사 과정을 지나올 수 있었습니다. 이번 논문 심사를 맡아주신 김관명 교수님과 박영우 교수님께도 정말 감사하다는 말씀을 올립니다. 부족한 부분이 많은 논문 초기 과정부터 끝까지 좋은 피드백과 진심 어린 조언들이 더 나은 결과와 방향으로 논문이 나아가는데 많은 도움이 되었습니다. 앞으로 세 분의 가르침과 조언을 마음 깊이 새겨 넣어 배운 지식을 토대로 사회에 공헌하는 강동훈이 되도록 노력하고 정진하겠습니다.

언제나 많은 도움을 주신 육기철 선생님께 진심으로 감사드립니다. 선생님의 도움이 없었다면 제가 이번 논문 주제를 만드는 시도를 할 생각조차 못했을 것이고, 중간의 고비마다 수고로움을 들이시면서 도와주셔서 정말 죄송하고 감사했습니다. 또한, 학생들을 위해 많은 도움을 기울여주신 행정실 선생님들께도 진심으로 감사드립니다.

오늘도 많은 순례자들에게 축성을 전달하고 있을 Br. Federico 에게도 멀리서 감사의 말을 전합니다. 주신 도움과 마음으로 항상 스스로를 돌아보고 마음의 힘을 얻어 앞으로 한걸음 나아가겠습니다. God bless you. Buen Camino.

곁에서 서로 용기와 지식을 복돋아주며 달려온 CDE 동기 여러분들께 정말 감사드립니다. 다들 자신의 장기와 특기들을 살려 노력하는 모습을 보며 저도 마음을 다잡고 달려나가는데 큰 힘이 되었습니다. 그리고 힘든 시기에 많은 도움을 주신 해빈형과 성준형, 중간에 큰 도움을 준 경룡과 홍민에게도 고맙습니다. 덕분에 항상 든든한 마음을 가지고 연구를 수행하고 석사과정을 거쳐올 수 있었습니다.

DECS 식구 여러분. 항상 우리는 함께 멀리 가는 연구실입니다. 이 마음과 가르침은 제가 연구실에서 배운 큰 지표 중 하나가 될 것 같습니다. 병헌과 하은에게 너무 감사하다는 말을 전합니다. 연구실에서 많은 도움을 주었고 제가 연구를 진행해 나가는데 있어 큰 힘이 되었습니다. 막바지에 많은 고생을 시켜서 미안한 수영, 지연, 윤정에게도 정말 감사합니다. 현재 옆 연구실에서 많은 일을 수행하고 고생한 성범, 성재, 병진에게도 감사합니다. 현재 각자의 맡은 바 일을 하고 있을텐데, 다음에 다시 만나서 감사함을 표현하겠습니다. 머나먼 곳에서 출퇴근을 하며 쉽지 않은 길을 오가면서도 항상 웃는 얼굴과 마음으로 인사를 해 주시고 조언을 해 주신 용섭형님께 짧은 기간이였지만 정말 감사했고, 앞으로도 DECS 에 큰 힘이 되어주셨으면 합니다. 익숙하지 않은 연구실 생활을 하면서도 많은 도움을 주고 힘이 되어준 Tima 에게도 감사합니다. 앞으로도 많은 사람들이 DECS 연구실에 들어오고 거쳐갈텐데, 저의 참 스승님이자, 어른이자, 지도자이신 이희승 교수님의 가르침을 따라 함께 더 멀리 가는 사람들이 되기를 기원합니다.

이 좁은 한장 여기에 다 담지 못한 고마운 많은 분들이 너무 많습니다. 보이지 않는 곳에서 학생들을 지원해주시고 매일 아침 인사를 밝게 건네 주신 이름 모를 여사님들과 행정실 직원분들, 연구원님들. 앞으로도 이 감사함을 항상 간직하며 살도록 노력하겠습니다.

이 연구는 2019 년 산업통상자원부의 재원으로 한국디자인진흥원의 지원을 받아 수행하였습니다.(N0001436)

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AngGo-N: Transformable Personal Mobility

Providing The Autonomous and Manual Driving Mode

This book is based on our Master Graduation Project but *not* an official publication.

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